The Institute of Physics

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The Bulletin is published by The Institute of Physics for circulation to its members.

Notices to Members

Oxford Convention

Programs and forms of application for the Convention are enclosed with this issue of the *Bulletin*. Members who would like to have forms for guests other than their ladies can obtain these on application to the Secretary.

Stimulation of entry to the Profession

The Membership and Examinations Committee has appointed a sub-committee consisting of Mr. G. W. Warren (Chairman), Dr. J. M. A. Lenihan, Mr. G. R. Noakes, Professor W. Sucksmith and the Deputy Secretary to consider and report upon additional ways in which the Institute could help to stimulate entry to the profession. When the sub-committee has completed its discussions the full Committee intends to hold a special meeting to consider its recommendations.

Revision of the lists of accepted qualifications

No major revision of the lists of degrees and other qualifications accepted by the Board as satisfying the academic requirements for membership has been undertaken for about sixteen years. The Membership and Examinations Committee believes that it is now time the whole matter was reviewed, bearing in mind the establishment of the Institute's Graduateship examination, a number of new degrees and diplomas of technical colleges. The revision will embrace the reconsideration of the qualifications giving partial exemption from the Graduateship examination. A sub-committee consisting of Dr. W. H. Taylor (Chairman), Professor M. R. Gavin, Dr.

K. A. G. Mendelssohn, Mr. G. W. Warren Professor J. G. Wilson and the Deputy Secretary has been appointed to make recommendations.

The Physical Society Exhibition

The Physical Society's 41st annual exhibition of instruments and apparatus will be held in the Halls of the Royal Horticultural Society, Westminster, London, S.W.1, from March 25 to 28, 1957 (inclusive).

Members of The Institute of Physics who are not members of The Physical Society may obtain tickets for the exhibition, available for any one day, on application to the Secretary of the Institute.

Remission of subscription of members of long standing

Fellows and Associates over the age of 65 years who have been members continuously for at least 20 years are reminded that they may, if they so wish, have their future annual subscriptions remitted. If they like to do this they will continue to receive the *Bulletin* and notices of Branch and Group meetings and may have the *Journal of Scientific Instruments* and the *British Journal of Applied Physics* upon the same terms as are current for students ; at present this rate is one guinea for each journal. Those who wish to take advantage of this ruling should notify the secretary.

Vacation students

For many years the Institute has helped students to obtain posts in industrial and other laboratories during the summer vacation. For the last few years this help has taken the form of inquiring about vacancies in laboratories and circulating details of available openings to heads of university and technical college physics departments. It is becoming increasingly clear that most universities and large technical colleges now have excellent relations with a number of industrial firms and have no difficulty in placing all the students who wish to have vacation posts. The Board has therefore agreed that there is no longer any necessity for the Institute to continue this work. If, however, individual students of the Institute have difficulty in securing places the Institute's permanent officers will be glad to do their best to help.

Sandwich course for laboratory technicians

We have been notified of a sandwich course for laboratory technicians which has been started at the South-East London Technical College, Lewisham. The syllabuses are those of the Intermediate Certificate of the City and Guilds Laboratory Technicians course (course 119). The course is primarily designed for the laboratory staff of schools and colleges but industrial organizations may find it useful for their technicians. Full details of the scheme, which involves two-and-a-half days' attendance each week, may be obtained from the Department of Electrical Engineering and Applied Physics at the college. It is understood that a similar course has been started at Paddington Technical College.

The scheme has been approved for deferment purposes.

Editor of Physics Abstracts

The attention of members is drawn to the advertisement on page viii announcing a vacancy for a physicist to edit *Physics Abstracts*.

Summer Schools

The University of Leeds Department of Inorganic and Structural Chemistry is holding a Postgraduate Summer School in Polarization Microscopy and Optical Crystallographic Methods from September 2 to 13. Further details and forms of application may be obtained from the Secretary, Department of Adult Education and Extra-Mural Studies, The University, Leeds.

The University of Sheffield, Department of Glass Technology, is holding a Summer School in Recent Developments in the Physics and Chemistry of Glasses from July 21 to 27. Further details may be obtained from Professor R. W. Douglas, F.Inst.P., Department of Glass Technology, "Elmfield," Northumberland Road, Sheffield, 10.

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Organization in Applied Science Laboratories

By J. G. DAWES, B.Sc., Ph.D., A.M.I.Min.E., F.Inst.P.

(*Safety in Mines Research Establishment, Buxton*)

INTRODUCTION

Scientists are sometimes charged with being less careful in the choice of methods and criteria for dealing with general problems than for dealing with their own special problems. Certainly, in Great Britain at least, there appears to be insufficient application of scientific method to the effective organization of laboratory work. It is first necessary to recognize that a particular organizational problem exists ; thereafter, the critical examination of the organizational methods employed, their classification and comparison, the possibility of experiment, the dissemination of experience, and the continual refinement of knowledge, will follow.

Organization could become as much a conscious aid for the applied scientist as the latest device described in a journal of scientific instrumentation, and yet, even in U.S.A. where the existence of the problem is widely recognized, most of the discussion seems to be carried on[1] by academicians, professional administrators, and an older generation of scientists who have not worked " at the bench " in the new conditions that have arisen during the last fifteen years or so. The contributions so made are essential and valuable, but in so far as the laboratory itself is concerned, men in everyday contact with the organization can make some contribution to its improvement.

This paper is an attempt to stimulate discussion amongst those directly involved in organizations in the applied science field. Although in practice in any one establishment there is usually a mixture of fundamental research, applied research, some development of equipment and methods and the provision of a routine scientific and technical service, the present concern is largely with applied research, which may be regarded as the solution of specific problems. The difficult problems of the choice of work to be undertaken and the technical methods to be adopted are not discussed—the concern is with the organizational environment of applied research.

AIMS OF ORGANIZATION

The job of the research worker may be defined as that of obtaining reliable and adequate information and of interpreting it in a way that leads to its greater understanding and application. When trying to solve a problem that has arisen he organizes and interprets existing knowledge, decides what data are missing ; and takes steps to provide them. Frequently, of course, the problem as originally envisaged is radically modified as work proceeds and new linkages between existing and new information are created which are of equal or greater importance than those initially sought. It then becomes possible to extrapolate the data to cover new situations and as the extrapolations are tested by experiment and observation, so knowledge increases. In this way, the attack on a specific problem often results in a gain in fundamental knowledge which can be applied elsewhere ; but to facilitate this, there must be time both for the contemplation of facts and for the exploration of side issues which often form the starting point for useful new work.

However, any attempt at prolonged concentrated thought on one problem is often self defeating. The pattern of thought, in the

absence of new stimuli, tends to become cyclic. It is therefore useful for the research worker, even during formal working hours, to be engaged in activities other than those immediately concerned with his main research topic. Since he is highly qualified and trained, such activities should have a useful and stimulating end, even though they may not be of immediate practical value to the employer. Also, the research worker may spend some time answering queries from the operative side of the industry served by his establishment. This not only benefits the industry, but also acts as a constant incentive to the worker to deploy his knowledge in new ways and to reveal where new knowledge is required.

Although these forms of "secondary" activities are beneficial, certain other secondary activities reduce the effective contribution of the research worker to the establishment. Such activities are the administration of standing orders governing conduct and procedure in the establishment, or the negotiation of contracts and the purchase of supplies. These activities are, of course, very important and demand particular skill for their successful achievement, but they do not afford stimulus to the research worker, indeed they often cause frustration as they prevent him from carrying out his real work. Consequently the object of good organization should be to protect the scientist from interferences and "red-tape."

As in other fields of administration, it is the responsibility of the "management" of a research establishment to remove obstacles to the orderly prosecution of work, to create a framework within which good working habits can be fostered and to establish channels for the execution of the necessary routine work. If this is done successfully by other personnel the research worker can devote his time to the speciality for which he is qualified.

Further, even in the research itself the effort of the research worker should not be dissipated by tasks that can be reduced to routine. Although the research worker must, if necessary, be able to perform most of the tasks required if he is to have an understanding of the work carried out and be able to interpret the results obtained in a satisfactory way, it is sensible that he be assisted by the work of personnel less qualified and less highly trained who can relieve him of the necessary chores of research.

In providing such assistance, however, great care should be taken that it does not result in "research by remote control." The research worker should be in close contact with the work being done and the only work delegated should be capable of immediate inspection and review. Otherwise, the stimulation of apparently minor anomalies in the observations made may be missed and the man responsible for the solution of a problem will not be able to make full use of the effort expended if he attempts to deal with data already processed by his assistants. He should examine the raw data and himself make the decisions on the processing necessary, even if himself he does not actually perform the necessary operations.

For these reasons, the personnel in direct charge of a research worker should be small in number and the range of topics which he is asked to cover at any one time small. Otherwise, there is the danger that assistants will, in effect, be in charge of research projects and the man qualified by training and experience to conduct research will find himself administering a large group of less qualified assistants and supervising a range of projects of which he has not got the intimate knowledge necessary, or the time for thought which is essential, if these projects are to be efficiently and successfully brought to completion.

At the same time, the nature of research tends to a concentration of the individual worker's attention on a particular set of facts or hypotheses; and such concentration, which is necessary for progress, can lead to an unbalanced view of a problem. Consequently, the efforts of the research worker must always be subjected to the temper of criticism. Continuous discussion is essential between those with a detailed, expert, and of necessity restricted knowledge of a given field of work, and those who, whilst not so intimately aware of the details, can yet set the work in a wider frame.

In order to encourage an unrestricted and willing interchange of ideas and information, in order to take advantage of the stimulus afforded by the thought and knowledge of even the most junior assistant in the establishment, the organization must be such that there is a free communication of ideas both up and down the line of seniority ; for, especially amongst juniors, there is exhilaration and a generation of goodwill in knowing what is going on. For this reason, the managerial concept of " good manners " is important. Decisions which affect the activities of members of the staff of the organization should only be made after free discussion with those affected, even if for wider reasons, based on an authority of ideas and experience, their own views cannot prevail. Withheld information and secrecy are antipathetic to that spirit of free inquiry which is characteristic of scientific activity, and dictatorial rule should give way to reasoned argument which if of sufficient power to justify action will win the approval of those concerned. If the research staff in an establishment cannot be trusted, and allowed full rein of thought, then either the morale of the establishment is bad, or the recruitment policy and conditions of employment have failed to attract the right people.

In brief then, the administrative effort of an applied research laboratory should be directed towards the support of the individual research worker by leaving him free for untrammelled creative thought, by encouraging free communication of ideas, and through a system of discipline based on the authority of ideas and experience and the broader view of the research program. Common objectives must be apparent, and staffs supporting the individual research worker must clearly understand their function.

PATTERNS OF ORGANIZATION

In all group activity, organization exists so that the required ends are reached more efficiently ; but it is necessary to recognize the difference between an organization devoted to the administration of set rules and one where there is a tangible and often material end product.

Organizational charts[2] are often based on concepts which originated in early forms of collective human activity of a military and political nature and their basis is authoritarian. The usual pattern is triangular with the principal officer at the apex. Authority is vested in him and he assumes responsibility for all functions. Such organizational patterns are appropriate where the aim is to provide a service based on established procedure.

In the field of research, however, success is determined by the efforts of the individual worker and the organization exists to support those efforts. Since creative thought can neither be predetermined nor delegated, the pattern of the triangle is not a suitable means of symbolizing the organization of a research establishment. A more appropriate symbol is the growing tree, with the research worker, in Oppenheimer's phrase, providing the growing points of new knowledge. Such a symbol places less importance on the research worker's status in a hierarchy and it emphasizes that the main function of the senior staff and of the " strut of authority " is to support the individual and to feed and stimulate his research activity. It further emphasizes the important fact that the qualified research worker should himself be fully active in the research projects in his charge, and should not be expected to accept a range of work much of which has to be delegated to less qualified assistants. With the triangular pattern of organization there is a natural tendency for delegation of function, which is often encouraged by the status conferred by subordinate staff.

SOME DETAILS OF ORGANIZATION

To illustrate the practical application of the concepts of support, stimulus, tidiness and good manners, a few aspects of laboratory organization will be discussed.

Terms of Reference

Although it would be foolish to attempt to establish the sort of rigid terms of reference that are frequently encountered in the triangle type of structure, an attempt should

be made to formulate some principles of action as a guide to behaviour. The ensuing tidiness will make it easier to allocate responsibility for various functions even if in practice these responsibilities are shaded by consultation (good manners) between one level and another.

The Research Director

The primary responsibility of the research director is the efficient attainment of the research objectives, his function that of providing the right research program, the right environment and the proper facilities for the solution of assigned problems. He must assess and procure the probable mental and physical resources necessary for solving the problems that may arise from requests by the sponsors of the research establishment, as the result of new knowledge won in the establishment, or that have been initiated by himself in response to stimuli received from his many contacts with both the organization and the industry it serves.

Other duties of the research director include :

(*a*) Recommending the selection and promotion of personnel,

(*b*) Supervision, co-ordination and control of the technical and non-technical activities of research groups and ancillary services, and the control of the personnel and organizational functions of the various groups,

(*c*) Analysis of problems in terms of their complexity and attributes and the feasibility of their solution by his establishment,

(*d*) Determination of the limits within which the resolution of a particular problem is of value,

(*e*) Final formal reporting of achievement and progress.

Further, and of paramount importance, the research director is responsible for the cultivation of a spirit of free and responsible inquiry, for the sense of a common objective amongst the members of the organization and for the avoidance of administrative breakdowns.

The Research Supervisor

The Research Supervisor is charged with the responsibility of making decisions which lead to work finished within acceptable limits, with the personnel, facilities, materials and time available. To this end it is often necessary to tailor the problems received, so that they can be tackled by the men in his charge and on a determined budget.

Amongst others, his duties include :

(*a*) Statement and general analysis of a problem before it is presented to the research worker and the formulation of what, provisionally, would constitute a solution of the problem,

(*b*) Review and approval of data, results, and conclusions,

(*c*) Approval of formal reports and the presentation of results to the research director,

(*d*) Recommendations on further activities for the men in his charge and supported by him,

(*e*) Control of expenditure for the projects in his care,

(*f*) Attention to morale and personnel requirements.

In so far as his other duties permit, the research supervisor should also guide the general orientation of the course of the theoretical, observational, and manipulatory work, comment on problems and results to help workers to arrive at solutions, and ensure the maintenance of efficient and technologically satisfactory methods of work.

The research supervisor should be in the position of being able to bring a wide experience to bear on the specific problems of the research worker, to stimulate him towards creative activity, and to secure for him effective liaison with other groups.

The Research Worker

As has been suggested earlier, the main function of the research worker in applied science is the solution of problems and this involves the handling and creation of information, particularly in so far as it involves the establishment of new relations between data.

His duties include :

(*a*) Studies of the literature concerned with the problem,

(*b*) Detailed analysis of the problem and the proposal of working hypotheses,

(*c*) Determination of the observations required to lead to a test of the working hypotheses,

(*d*) Direction of the design and construction of novel equipment,

(*e*) Identification of suitable commercial equipment and the initiation of its purchase,

(*f*) Conduct of experiments and the collection or the direction of the collection of data,

(*g*) Manipulation and calculations involved in correlating and deciding on the significance and relevance of data,

(*h*) Formulation of solutions for the problem,

(*i*) Presentation of results,

(*j*) Formulation of new, potentially useful, inquiries which arise out of the investigations carried out in search of a solution for the assigned problem.

Development of Individual Abilities

An effective organization must recognize that provision must be available for differently developing abilities among its research workers, or it will lose the talent and experience which it has been responsible for developing.

In an applied science research establishment, the newly qualified recruit from the university poses a special problem. Before he can become fully effective as a creative research worker with a responsible attitude to the objectives of the organization, he must acquire not only a knowledge of the industry served by the establishment and an interest in its problems but also genuine self-confidence. This takes time, and to serve such an end one proposal is that he should work as an individual under the guidance of an established research worker and be given a problem which it is fairly certain can be readily solved. It is advantageous if the problem can be of a fundamental nature, for this gives a good background to later applied research, and an attempt should be made to produce a dissertation in a form suitable for publication. This will engender confidence, and the study of the fundamental topic may either lead to a real interest in one of the existing problems of the establishment or may be so developed until it becomes part of the accepted program of the establishment.

Even when research workers are established in their own right, and part of the creative team in the organization, different kinds of ability will come to the fore. Some men can remain creative and lead in their subject throughout most of their working lives. If this subject is of continuing interest to the organization, the promotion policy should be such that the material rewards of such a man do not depend on his becoming a research supervisor and so being removed from the stimulation of direct contact with his chosen field of study.

If the management and organization of the establishment are good, it should be possible to promote research supervisors from the research worker level, without any special training being necessary, for the habits of work and behaviour should be well established by the example of the existing senior supporting staff. Such vertical promotion should not, however, be the only outlet for developing talent and experience. There should also be lateral promotion of the research worker to such tasks as the provision of an advisory service or the performance of particular tests for the sponsoring industry, or to the institution of a regular testing service for the industry.

Thus, the close collaboration of an applied science research organization and a control and testing organization which uses more routine applied science is doubly beneficial. The latter acts as a stimulant to the activities of the former, and it also provides an outlet for the men of experience which the former has developed and so preserves them for the service of the industry concerned.

Planning of Research

As far as the establishment as a whole is concerned it is desirable to have a catalogue of future research projects as well as a current research program. Items may be added to this catalogue after discussion amongst responsible men in the organization and the

sponsors of the research, but it is advisable that they are not placed on the research program until the decision is deliberately made to assign them a priority ; otherwise there is the danger that the research worker will have his efforts dissipated in a multitude of problems, to none of which he can devote the necessary concentration. With this there is the allied danger, previously mentioned, of the delegation of problems to research assistants and the attempt at research by remote control.

It is one of the tasks of the research supervisor to re-form problems for solutions into research projects, and these should be assigned to the research worker, on an understood priority, after consultation with both the research worker himself and the research director. One suggestion is that no research worker should have assigned to him more than three projects at any one time. The projects will usually all be in the same field of specialized knowledge. A priority scale which could be assigned is :

Standard—A main project, to be continued on a long-term basis.

Standby —A job to be undertaken if a standard priority task is held up for reasons outside immediate control.

Reserve —To be done only at time when no other tasks are on hand.

As work is completed, remaining projects are moved up the priority scale and others are added from the catalogue.

In order to deal with important inquiries and special short-term research projects which may be necessary in " emergency " conditions, it is useful to have two other priority classifications, namely

Immediate—Other work to be put on one side —continue until the task is finished.

Urgent —Complete if possible within x days (the interval chosen by the research supervisor). If not possible, prepare an explanatory report with an estimate of the time required for completion of the task.

Applied science research can only be planned to a limited extent. It is possible to define a problem, decide who shall undertake it and when, and (in outline at least) indicate how it shall be tackled. But the detailed form of the solution to the problem, even the possibility of a solution of the type initially envisaged cannot be guaranteed, nor of course can the time required to obtain the solution. However, without some form of planning, there is likely to be misdirected and wasted effort, and the time taken to provide solutions to essential problems will be greater than it should.

Planning the provision of facilities and outlining the steps in the progress towards a solution of a problem is, however, possible, and the use of Gantt charts[2] (in modified form) by the Research Supervisor is useful. Such charts, in the modified form, only make the most tentative estimates at timing the various phases of the work, and it is essential that flexibility be retained, for the direction and phasing of investigations may be modified as work proceeds.

A useful device for the research worker is the preparation of a sketch of the research paper which might be expected as a result of the work to be undertaken. The final report will very often be completely different in form and content from that expected at the start of the work, but the device focuses attention on the logical development of the investigation and the missing areas of information.

It is essential, in all the planning, that those taking part in the work are consulted at every stage, so that in effect the commitments are self-imposed and acknowledged as realizable by those who will carry out the investigation. It is particularly useful to get the research worker to produce his own statement of the problem, which can be approved by the supervisor before work starts. In this way misunderstanding and waste of effort are avoided. The relations between the research worker and the assistants in his immediate charge should also be on the same basis. It not infrequently happens that even the most junior members of an organization can make a contribution or stimulate thinking which leads to the more efficient prosecution of the work in hand. Apart from this aspect, the consultation and discussion involved not only serve to maintain high morale in junior staff

and to contribute to their development and training, but impose a fruitful discipline on the more senior ranks, for if they cannot formulate the problems in understandable specific terms, it is likely that they are not themselves clear about the objectives being pursued.

Records and Reporting

It has repeatedly been emphasized that research is firstly the discovery and then the organization of information in fruitful and verifiable patterns and consequently it is of utmost importance that attention is paid to the proper recording of data and also of the events leading to the creation of new information. Many organizations have a central registry where records are kept of the decisions and the basis of the decisions leading to action in pursuit of the ordinary objectives of the organization. Such a system is necessary in an applied science research laboratory to carry on the general business of the establishment especially in so far as it is concerned with contacts with outside bodies.

Final reports on research projects should also be placed in the central registry so that they will be permanently available for reference. Even during the development of an investigation it is a useful guiding principle that a formal typewritten report is placed in the registry whenever a piece of work has reached a stage that justifies such a report.

Such a records system, however, needs supplementing by a method of preserving the detailed information which is the working material of the research worker and his immediate superiors. For this reason a system of working files, in the charge of the research worker, is of benefit.

The responsibility for starting a working file should lie with the research supervisor, and the first document in it should be his statement of the objectives of the project and his suggestions about their fulfilment. The research worker's own concept of the problem should be his first contribution to the file.

The working file should contain :

(*a*) a priority sheet recording the current priority of the project and should give cross-references to other working files on similar projects and to the appropriate central registry files.

(*b*) a minute sheet, which acts as a brief, dated record of actions taken and approvals given and which serves as an index for the main body of the file,

(*c*) notes on exploratory within-unit discussions,

(*d*) the details of exploratory work, with a summary of that work,

(*e*) a record of primary results in the form of original data sheets,

(*f*) the primary condensations of experimental results recorded on working sheets,

(*g*) computation sheets used in analysis,

(*h*) exploratory plots of results,

(*i*) " try-out " mathematical theories and the detailed development of those theories,

(*j*) interim results in final tabular and graphical form (copy to be placed in the central registry file),

(*k*) initial drafts of reports.

The preparation of formal reports on all investigations even if the investigations have not lead to what was originally conceived as the desired end is, of course, essential in an applied science research laboratory. Such reports are the end-product of research, and if they are not produced then the effort expended on investigation is wasted. But they are more than this, they are also an effective tool of research, for when undergoing the discipline of their preparation, the research worker is obliged to create logical patterns which often tend to expose weaknesses in the data being reported on, and on occasion lead to the revelation that certain data are missing. Moreover, the preparation of reports supplies the opportunity for reflection on the data collected and not infrequently results in a re-organization of the findings in such a way that new relationships are revealed. In these ways, report preparation can provide the starting point for new series of investigations, the necessity for which would not, perhaps, have been revealed without the conscious effort at organizing information which is the essence of report writing.

The Stimulation of Research

The methods for stimulating new ideas suggested previously, can be supplemented by a number of others. These include :

(*a*) the review by the research worker of scientific abstracts and papers outside his own immediate field of study,

(*b*) attendance at external conferences, meetings of scientific societies, exhibitions of scientific instruments, etc.,

(*c*) holding of internal colloquia and meetings ranging from the informal " Rutherford tea-party " to formal conferences.

(*d*) discussion with qualified consultants from outside the organization,

(*e*) creation, in conjunction with allied organizations, of panels for the discussion of particular topics,

(*f*) Discussion, with an advisory body composed of experienced men in the industry served by the establishment, of the research carried out.

All these activities absorb energy and time, but their value must be recognized and the research worker's time so freed from routine duties that he has the opportunity to benefit from them.

CONCLUDING NOTE

This paper only presents raw material for consideration, discussion, and challenge, and not a final exposition of an art. What is required is an intermingling of experience, the creation and test of criteria of success, and analysis directed to the identification of factors which are of importance in different conditions. It is hoped that the paper will promote some interest in organization as a topic for study and will lead to beneficial discussion.

REFERENCES

1. Bush, G. P., and Hattery, L. H. *Scientific Research: Its Administration and Organization.* The American University Press, Washington, D.C. (1950).
2. Elbourne, E. T. *Fundamentals of Industrial Administration.* Macdonald and Evans, London (1936).

Reviews of Books

PULSE AND DIGITAL CIRCUITS
By J. Millman and H. Taub

London : McGraw Hill Publishing Co. Ltd. Pp. 685 + xvi. Price 94s.

Until a few years ago electronics—meaning here circuitry or electronic engineering—was almost synonymous with radio engineering. This book brings out very clearly the extent to which the scope of electronics has widened in recent years since its more than 600 pages are devoted almost entirely to electronic circuits that are not usually found in radio systems.

Perhaps the most important difference between the old and the new electronics is that whereas the waveforms involved in radio engineering are essentially sinusoidal in nature, a much wider variety of waveforms is encountered in the newer branches of electronics. In addition to the operations of amplification, modulation and detection, circuits are now required to perform many additional operations such as waveshaping, amplitude or time comparisons, and clamping. Most of these circuits depend for their operation on the use of non-linear circuit elements, and are required to function over much greater bandwidths than the conventional radio circuits. These and other differences mean that the electronic circuits used in radar, television, computing, control systems, nucleonics and other fields are often clearly distinguished from the classical radio circuits and can conveniently be studied separately after these.

This book is intended as a textbook of electronic circuits other than those found in radio systems. As a textbook for undergraduate courses it will therefore be of interest primarily to students of electronic engineering, but it is also suitable for postgraduate courses and should be very useful to physicists working in the newer branches of

electronics. The treatment is unusually thorough and, as the principal emphasis is on a deep theoretical understanding of pulse and digital circuits and techniques, it should appeal even to those who, in the ordinary way, regard electronics as a somewhat inferior branch of knowledge. The circuits described are analysed on an essentially physical basis, mathematical solutions being accorded only secondary importance. There is a short section on semiconductor physics to introduce the transistor as a circuit element, and a chapter on its use as a switch in pulse and digital applications. The use of magnetic cores in binary operation or as pulse transformers, and of gas-filled counter tubes is also included. The book includes over 400 problems for the student in addition to a large number of illustrative examples worked out in detail in the text.

The early chapters deal with the response of linear networks, both active and passive, to the types of waveform commonly encountered in pulse circuits. Then the basic non-linear behaviour of vacuum tubes and semiconductor devices is described, and the effect of this on waveform transmission is studied. Waveform generating circuits and other fundamental circuits are then analysed in detail and finally, and occupying about one half of the book, the basic circuits are assembled into pulse and digital systems.

A basic knowledge of classical electronic circuits is assumed but the special nomenclature of pulse and digital circuits—totem-pole, amplifier, boot strapping, multi, and multiar, etc. !—are all explained. The book is handsomely printed and produced and no more than minor misprints have been noticed in the text.

A. E. De Barr.

CURRENTS, FIELDS AND PARTICLES

By F. Bitter

London : Chapman & Hall Ltd. New York : John Wiley & Sons Inc. Pp. 599+xiv. Price 68s. Second Edition

This book is essentially on electromagnetism but with a difference in that the experimental aspects are stressed much more fully, and are interwoven more closely with the theoretical work, than is the case with more normal textbooks on the subject. Maxwell's equations, in integral form, appear on page 234 almost, one feels, too apologetically. Briefly, the contents in order lead from electric fields, magnetic fields and electromagnetic theory to the Poynting vector, radiation of waves and physical optics (there are only about 60-70 pages on the latter). Then a chapter on atomic physics follows (" waves and particles," etc.) which briefly treats with various topics such as X-ray crystal optics, electron and neutron diffraction and quantization. The next chapter is on wave mechanics and the book is concluded with brief chapters on atomic physics and finally nuclear physics.

The whole work is attractively arranged and covers the above wide field expertly. The author, distinguished for his work on magnetism, includes some unusually good iron filing pictures of fields. Fig. 1.14 (p. 20) which shows the magnetic field of a current is unusual. There are many problems, arranged at the end of each chapter, but, surprisingly, no references to the original literature.

The book can be highly recommended, although its price may put it beyond the average student's means. The technical production is of the highest standard.

J. D. Craggs.

PRINCIPLES AND TECHNIQUES OF APPLIED MATHEMATICS

By B. Friedman

London : Chapman & Hall Ltd. New York : John Wiley & Sons Inc. Pp. 315+ix. Price 64s.

This book discusses Linear spaces, Spectral theory of operators, Green's functions, Eigenvalue problems of ordinary differential equations, and partial differential equations, in successive chapters. It is concerned with mathematics which may be applied, rather than with " applied mathematics." In fact the only application, a discussion of the passage of a plane light wave through a pane of glass, is introduced only to formulate a suitable boundary condition at infinity.

It is addressed to physicists and engineers, though it demands quite extensive knowledge of mathematics, particularly linear algebra and complex integration. The emphasis is consequently on methods rather than abstract theory and the text is illustrated by many examples and problems. Many details and extensions of the text have been put into problems. In one or two cases the "hints" given in connection with the problems are not very helpful.

The attempt to provide an introduction to Schwartz's Distribution Theory is not wholly successful and needs to be thought out more carefully. There are some inconsistencies and occasional looseness of expression. Nevertheless the author is to be thanked for making the attempt. The discussion which will be stimulated will, no doubt, lead to a more satisfactory introductory treatment.

This book can be recommended to physicists with an interest in mathematics, who will find it a useful book to place alongside Courant and Hilbert.

A. W. GILLIES.

ATOMIC QUEST

By A. H. Compton

London : Oxford University Press Ltd. Pp. 370 + xix. Price 30s.

This is an account of the exciting drama (some will say tragedy) of the building of the first atomic bombs, as seen by one of the most prominent actors in it. Into the story has gone everything that Compton has thought to be significant between the time when he discussed with E. O. Lawrence and J. B. Conant the possibility of the development of an atomic weapon—in the autumn of 1941—to the fateful day four years later when the first atomic bomb to be used in warfare was dropped on Hiroshima. Compton was throughout closely aware of, and had much responsibility for the solution of, the enormous scientific, engineering and administrative problems that arose. It is a frankly personal story and I think is the better for being so ; no doubt anyone who was personally concerned with this search for a glittering military prize could read the book and feel that a different emphasis should here and there be given, or that various people not mentioned ought to have been given credit for their share of the work. But Professor Compton has not attempted to write an official history of the atomic bomb project. He tells the story as he experienced it. His style is simple, in places rather heavy, and with little literary grace or subtlety. What clearly emerges from the story is the remarkable, selfless devotion that was shown by thousands of scientists and engineers in applying everything they knew to a problem that often must have seemed impossible of solution in the time likely to be available. Revealing personal sketches of some of the principal colleagues of Professor Compton are included in the story.

Perhaps of special relevance to some problems of the present time is the account that is given of the discussions of the "Interim Committee" set up to advise President Roosevelt upon the development and control of atomic energy and upon the use of the atomic bomb. The author's brother, Karl T. Compton, was a member of the Committee and A. H. Compton was a member of the scientific panel that advised the Committee (the other members being Fermi, Lawrence and Oppenheimer). A. H. Compton himself attended several of the Committee's meetings.

The book also contains lengthy accounts of Compton's religious views and of his interpretations of the moral issues arising from the use of atomic bombs. There will be many who, like myself, find these parts of the book naïve and wholly unconvincing. It is perhaps ironic that one who played such an important part in the development of the most devastating weapon in the world's history should be descended from Mennonites, a Protestant sect of whom Professor Compton says: "pacifism is to them a deeply fundamental doctrine." They are one of the historic pacifist churches and Compton's grandfather was a conscientious objector who would take no part in the Civil War.

NORMAN CLARKE.

AUTOMATION : ITS PURPOSE AND FUTURE

By Magnus Pyke, B.Sc., Ph.D.

London : Hutchinson's Scientific and Technical Publications. Pp. 191. Price 16s.

In this book, which is unlikely to be of value to readers of the *Bulletin*, the author attempts to review the developments of " automation " and their effect on a wide range of industries and on the social and economic life of this and other countries ; he gives a sketchy account of some of the machines such as the digital computer. Among the overstatements and errors in the book are the following :

P. 23 " . . . investigators publish reports in the scientific ' literature ' every few months whether they have any discoveries to announce or not."

P. 27 " In the old-fashioned radio ' crystal set,' electrical impulses were converted into sound waves by means of a quartz piezo-electrical crystal."

P. 136 " It is within the realm of possibility that milk may one day be produced . . . without the need for a cow at all."
P. 165 " . . . there are almost no scientists left to teach."

The author appears to regard almost any mechanical device as a form of " automation," and tells us (p. 123) " that ' automation ' is the most advanced state of mechanization." Thus at p. 123 there is a discussion about " penny-in-the-slot " machines and on p. 129 about the removal of the droppings from hens by an endless conveyor belt.

The last chapter which attempts to answer the question " How will it feel to live the ' life automatic ' " is a mixture of politics, ethics and speculation which will be of interest to those who like such exercises and fantasies. It is only just, however, to record that the author opens his preface with the words " scientists do not, as a rule, distinguish themselves as commentators on general affairs."

There is no index and there are no references to enable a reader to follow up points which are not clear or to examine the many quoted statements in their original context.

H. R. Lang.

DIGITAL CALCULATING MACHINES AND THEIR APPLICATION TO SCIENTIFIC AND ENGINEERING WORK

By G. A. Montgomerie

London : Blackie & Sons Ltd. Pp. 262. Price 30s.

To imagine what it would be like to take a correspondence course on how to ride a bicycle gives one a good idea of the impression created by this book. As the author himself says, a few hours with an actual calculating machine will teach more than can be learnt from reading. The book is essentially a collection of slightly amplified instruction manuals, such as makers usually supply with their machines. Examples of the standard types of desk machines are included, the descriptions for the most part being of the controls and registers, and how to manipulate them in order to carry out the basic processes of arithmetic. Only occasionally are odd scraps of information about internal mechanisms given. The latter chapters, dealing with punched-card equipment and automatic digital calculating machines, are more readable, though there is little that has not already been well written in earlier books. There is not much justification for the extended title, and anyone expecting to find applications to scientific and engineering work will be disappointed.

The reviewer regrets that he cannot raise more enthusiasm for the subject matter of this book, particularly as it is very well produced and contains numerous, informative photographs of calculating machines. On these grounds it can be recommended to those who have a use for an elementary, but reasonably comprehensive, handbook of digital calculating machines.

J. Crank.

Degree and Diploma Courses in Applied Physics

(continued)

SECOND SESSION

Thursday, November 15, at 2 p.m.

Chairman : SIR GEORGE NELSON, M.I.E.E., M.I.Mech.E., F.C.G.I.

(The English Electric Co. Ltd., London)

Sir George Nelson

I have the greatest pleasure in asking Professor Blackett to give his address. He needs no introduction to a meeting having in the forefront of its thoughts the subjects with which this conference is dealing. His work has been widely recognized, by the award of the American Medal of Merit in 1946, the Nobel Prize for Physics in 1948 and the Copley award of The Royal Society this year.

Professor P. M. S. Blackett, F.R.S.

(Imperial College of Science and Technology, London)

It is very useful to me as a Professor of Physics to hear the opinions of employers as we have heard them this morning. A good deal of what might be called "market research" was discussed—what employers say they want. Naturally the more that we who train physicists, and who can control to a very considerable extent the nature of that training, know about employers' views of their wants, the better ; but we shall not necessarily agree to satisfy them.

We shall find, when we look into it, that many of the suggestions for improving the physics courses for the B.Sc. cancel out. Some people want less knowledge and deeper thought, while others want a wider grasp of more subjects. Sir John Cockcroft thought that the Cambridge Natural Sciences Tripos is woefully out of date and leaves too little time in the third year for advanced work. On the whole, I think I agree with this and hope that changes will be made. However, shortly after hearing Sir John's speech, a distinguished colleague of his told me that he took the old Natural Sciences Tripos Part I and has since found the breadth of knowledge acquired of inestimable value. Here we see two views, by people of eminence, which cancel out.

The fact is that we find a variety of different ways of teaching science practised at the moment in this country, and even more so over the world as a whole. Moreover, it is evident they can all lead to good results if well done. In fact, I do not believe that it would be possible, without putting the specific question, to discover, five years after graduation, how a particular scientist had been educated. The extent of the variety in this country ranges from the broad Natural Sciences Tripos of the Cambridge system on the one hand, to the specialist honours schools in most of the provincial universities on the other. The period of the degree course is usually three years, but is four years in a few places and only two years (that is, of organized teaching) in others. The final product does not seem to me to differ very much.

I am thus inclined in general to express

rather conservative views about the quality of British university physics teaching and to say that, on the whole, I think the universities are doing a good job. In particular, I think that the physics graduate is a good product and, with some reservations, I do not believe that we need much change within the limits of what is possible at the moment.

There are some changes, however, which I do think are important. I agree with Sir John Cockcroft that, on the whole, British physicists are not very well equipped to use mathematics easily and quickly as a tool in their researches. This has partly a historical origin in the traditional divorce between the faculties of mathematics and pure science in many universities in this country. There is no such divorce in many other parts of the world and in some universities in this country, and our deficiency in this matter could be remedied here with relative ease. But it has not been remedied generally ; it has not even been remedied at Cambridge, for instance, after many years of consciousness of the problem.

I ought in passing to mention one of the main subjects of this conference, which I understand to be Applied Physics as an alternative to present physics courses for the B.Sc. Like President Coolidge in his attitude to sin, I am against it—as a general rule. Applied Physics as distinct from engineering, in my opinion, should be in general a postgraduate activity. In a pure science experimental department, specialist postgraduate teaching, as contrasted with research, has not as great a role as in engineering and technology, where it is increasingly important ; it may, however, be of great importance in such subjects as mathematics and theoretical physics.

In the Physics Department at Imperial College there is, for example, a school of Applied Optics under Professor Wright. This department is autonomous at a postgraduate level, but does not give a B.Sc. in Technical Optics. I think it would be a bad thing if it did do so. We have also a department of Instrument Technology under Professor McGee, organized in the same way and not giving its own degree.

Postgraduate specialization is extremely important, and this is where big changes are needed and are in fact imminent. Having taken a basic degree in pure science, for instance in physics, chemistry or mathematics, which form much the largest numerical group, students could, and often should, go on to do a one- or two-year tuitional course in some specialized subject. These will probably be in engineering of some kind, but may also be in some applied science, or in theoretical physics, etc.

The desirability of encouraging further specialized tuition after the B.Sc. has just been recognized by the Government as important. A few days ago it was announced that next October the Department of Scientific and Industrial Research will award a number of postgraduate advanced training grants, quite distinct from the postgraduate research grants which have been the mainstay of the postgraduate schools for the last two or three decades. This is something new. There will be initially 200 of these grants, and they will be given for six months to a year or more. They will enable a student who has taken a B.Sc. degree in a basic subject to stay on in a university and become a specialist in some related subject. There is no research involved in this award. This is the beginning of a movement with the initiation of which Imperial College (under its late Rector, Sir Roderic Hill, and its present Rector, Dr. Linstead) had a good deal to do. It means the provision of finance for postgraduate teaching rather than only for research.

There is also the important question of how to get senior men in industry to come back for a time to the universities. At the moment the special awards I have mentioned are intended mainly for people straight from their first degree or who have done a few years only in industry. I think that in the next few years the main financial responsibility for sending more senior men back to the universities for advanced courses will lie with industry.

When the new D.S.I.R. scheme is working it should give us a very good way of producing the " hybrids " mentioned this morning, and

which I agree are a very good breed—a physicist turned aeronautical engineer, a mathematician going into engineering, a chemist going into one of the many branches of chemical technology. These can be extremely valuable people, and they are best produced by a first-class pure science training, on which afterwards is grafted a particular technology. By the time a man has taken his B.Sc. he should be old enough, and we may hope wise enough, to know what he really wants to do. The disadvantage of the specialized B.Sc. course is that a boy has to decide too early what special subject to take up.

There are, of course, other changes in our curricula which might in principle be good and might allow us to meet some of the criticisms. I accept the view that none of our courses are perfect : with human fallibility there is bound to be a good deal to criticize. A four-year B.Sc., for instance, would allow us to go slower and not rush people so much and so would have great advantages. However, it is impossible in general at the moment because of building difficulties and the approaching "bulge." Even if it were advisable, it cannot be done now because we did not prepare for it years ago by providing the necessary increased accommodation.

What is more important, in my view, is a possible need to reinstitute a preliminary or intermediate year for those who at school had studied arts, or science to a less specialized extent than at present. In such an intermediate year one would try to get the students up to the level of the beginning of an honours course in pure science subjects. Experiments of this kind are going on at Oxford, Liverpool, Imperial College, Cambridge, Durham and Birmingham and other universities. The boy or girl who has taken primarily an arts subject, preferably with a little mathematics, could thereby change over to science and be specially trained to enter the honours course a year later. This means an extra strain on accommodation, but I think it is at present a much more important use of available accommodation than to add a fourth year on to the end of the course. I would be against a four-year B.Sc. course, even if the space were available, until compulsory military service for scientists has stopped ; for it would add yet another year to the age at which young men entered their professional career.

I want now to refer to research in the fundamental sciences in the universities. This is often extremely exciting, and it is not a little due to this excitement that a greater number of boys and girls than ever before are taking science. It is the excitement of the new developments in nuclear physics, radio astronomy, the big accelerating machines and other researches on the frontiers of knowledge which are interesting the youth of the country in physics and making them take it up as a career, and so indirectly and in the end adding to the supply of scientists available for industry. It is extremely important that the universities do not deliberately make their physics courses duller with the supposed intention of training students more directly for industry. If we want, as surely we all here do, to divert more school children from arts into science, we shall not do so by trying to persuade them to leave, say, a good career in the humanities to take a B.Sc. in some specialized and hardly known technology.

I think that the large and unexpected rise in the number of science students now coming to the universities is due to a considerable extent to recent publicity about the value of science to the community and also to the excitement of science as a pursuit. It is extremely important, therefore, that our universities should be exciting. In a sense, the prize of a research career in fundamental science and the possibilities of world fame are the field-marshal's baton in the student's haversack and a great stimulus to hard work. We must not weaken that incentive.

At the opening of the conference Mr. Humphreys mentioned, and quite rightly, the importance of numbers. That is not the subject of this conference, but I think that it is necessary to say a little more about it. The number of scientists and engineers is the one thing which in my view is really important to-day. Debates about the details of courses, in my view, are unimportant by comparison.

The question of numbers is overwhelmingly serious. The figures for the U.K., the U.S.A. and the U.S.S.R. have been extremely carefully worked out and are given, for instance, in a recent White Paper. Russia produces twelve times as many applied scientists and engineers of graduate status as we do, which is three times as many per head of population. No amount of fiddling with curricula is going to make much impact on numerical differences of this magnitude. We must all—the Government, industry and the universities—take the responsibility for this situation arising. We started very well immediately after the war by doubling the output of university scientists and engineers in the three or four years. After that, however, an extraordinary period of inaction set in. Views were officially expressed that we were likely to over-produce physicists and chemists, and that there might be little for them to do but teach. That was the atmosphere in 1949 and 1950. From that time dates the failure to follow up the good beginning of the Barlow expansion period.

The universities are now desperately short of space for further expansion. Moreover, we are now faced immediately with what in educational circles is called the " trend," the tendency for more boys and girls to stay on at school in the sixth form and then go to a university, and will soon be faced with the " bulge," that is, the increase in the birthrate at the end of and just after the war ; this will reach its maximum effect in a few years. Both these effects will put a big strain on university accommodation, and the country has nobody to blame but itself for the fact that the buildings, and even the sites for them in some cases, are not there. The failure is extremely grave ; moreover, it is not a failure of real resources ; the amount of building of other types going on in this country shows that there is no lack of building materials.

Whatever we do about it, there will clearly be an extreme shortage of scientists in the future ; and this is where we all, and not only industry, have greater responsibilities, as Mr. Humphreys emphasized this morning. In my view, even if we do our utmost in the provision of buildings, in altering school curricula, in instituting a preliminary year, and in all the other ways we can think of which are possible administratively, we shall still be extremely short of scientists. So we have to study the problem of how best we use them. It comes down to the question of the size of the cake that we have to cut and the share which should go to each of the interests concerned. The discussion of curricula is like discussing the particular shade of brown to which the cake should be baked. In my view it is the size of the cake and the use which is made of the slices rather than their colour which are important.

This question of the use to be made of scientists is very important and wants much more study. Fortunately, a useful book has just been published called *Graduate Employment*, by P.E.P., which gives all the statistics that anyone can want to have about graduates, science and otherwise—what jobs they take to start with, what they get, how much more or less they get in a certain job if they went to one school rather than to another, how many left their jobs after a certain time, and so on. All this information is very valuable. It confirms, among other things, what one knew already from private contacts, and which is an important point for industry to remember, namely that industry is not keeping even all the graduates that it recruits when young (see Tables 68 and 77). An appreciable number of scientists do not apparently find industrial research congenial, and seek, even if it involves a reduction of salary, to move to a university or research institute. This is something which industry must look into. I do not know enough about industry to know the reasons.

Even when that has been done and industry gets its fair share of the cake, there remains the question of what work these men will be given to do. This is far outside the scope of the present conference, but I feel it may become the major issue in the future. In my view, both in the universities and in industry, this country suffers from too many subviable groups of people working on too small a scale to make a substantial impact on their science or technology. I

have come across this often in my personal experience.

I have deliberately gone away from the official subject, which is degree courses in applied physics, because I do not think it is a very important question compared with the problem of the supply of scientists and the use to which they are put.

DISCUSSION

Sir George Nelson : We are most grateful to Professor Blackett, and I am myself particularly grateful to him for his inspiring address. We are, of course, gathered here to review the possibilities of changes in the curricula of universities and technical colleges to meet the needs of industry, but I am delighted that he has raised some points about industry itself. They are very justifiable, and perhaps later in the discussion I may say a few more words on the subject. I now invite Professor Greig to open the discussion.

Professor J. Greig (*King's College, London*) :

[Professor Greig first commented briefly on the papers which had been presented. He expressed special interest in the remarks which had been made in favour of the establishment of courses of postgraduate study, and he suggested that provision for taking the Master's Degree by examination as an alternative to research was a valuable development which merited encouragement.

He then turned to the relationship between applied physics and engineering.] It is important to recognize that while engineering is in a sense simply applied physics, the real distinction is one of aim. The aim of the engineer is essentially " constructional," while that of the physicist is "investigational." Although research plays an exceedingly important part in engineering practice, the engineer does not normally pursue research for its own sake, but does so in order to achieve some useful result. Many engineers are engaged in design, construction and operation, and only a proportion of engineering graduates make their careers in research. Those who do, however, present a problem in relation to the organization of undergraduate courses. The three- or four-year course is already overloaded, and for the engineer who is going to pursue a research career, the content of advanced mathematics and physics is deficient. There is, in my opinion, a real need for a postgraduate course for engineers which will give potential research men an introduction to modern physics, to more advanced mathematics, and to what, for want of a better term, I may call advanced fundamental technology. Advanced fundamental technology would comprise such subjects as Theory of Automatic Control, Information Theory, and the Application of Tensor Analysis to Systems. In point of fact, the engineer who is going on the research side must make himself something of a physicist.

There thus remains the basic problem if we are to attempt to differentiate between physicists and engineers in the research field. My attempts at definitions which would provide some differentiation are as follows : Physics is the study of physical phenomena ; applied physics is the investigation of physical phenomena for useful purposes ; engineering is the application of physics to the devising of methods of design of systems and constructions, and of methods for the analysis of their behaviour. It is the " ingenium," the devising and contriving, which puts the engineering content into engineering. When we come to differentiate between engineering and applied physics we are in the difficulty that there is not the clear difference of aim that there is between pure physics and either applied physics or engineering.

In conclusion I should like to mention something which is, no doubt, known to many of you, namely, that Ewing presented to this Institute in 1922 a lecture entitled " Physics for the Engineer." From this I should like to quote a short passage :

> " There are three main ways in which the study of physics may and does profoundly influence the development of

engineering. The first is when the development of physics determines the immediately creative work of the engineer. . . . Another way is when the physicist himself makes an advance in the principles of his science of such a nature as to illuminate the operations of the engineer, systematizing what was before haphazard and vague, clarifying the ideas and directing the efforts of the practical man, sometimes by showing him what was impossible and sometimes by revealing possibilities not yet fully explored. It is mainly by such steps that the theory of engineering progresses. . . . Then there is a third way. It may happen—it has often happened—that the progress of physics affects that of engineering without intention on the part of the discoverer and without recognition of the practical bearing of the discovery."

Dr. H. O. Puls (*British Nylon Spinners Ltd., Pontypool*) : I am sorry to have to quarrel with such an eminent physicist as Professor Blackett. I think that I speak on behalf of at least some industrialists ; if I understood him correctly, what he was trying to provide for us was quantity and not quality. We are not interested only in quantity ; we also want quality. When we are given analogies with the army, we have to remember that an army must not only be large but know how to use the weapons with which it has been provided. That is the first point which I wish to emphasize. The physicists which we so often interview for posts in industry are very inadequately equipped, and I mean equipped in all senses of the word.

They are inadequately equipped in fundamentals. I think that the reason for this has been touched on already ; they are not taught, as Dr. Thomson in particular suggested that they should be, in a unified way. There are too many separate little bits here and there, and they never seem to connect them up. Secondly, they are not taught—and here I am exaggerating deliberately—to use the tools of their trade. It may be difficult for you to believe it, but I have had to face young graduates with good honours degrees who have never handled a microscope, who do not know how to set it up and who do not know the theory of it or how to use it. The same is true of the cathode-ray oscilloscope and the amplifier. Why is this ? I suggest that the answer has very largely been given already, that there are so many things that they have to learn that some things must be omitted.

I may have been unfortunate in putting these particular questions to these young graduates, but I feel that the time that they spend in the university is too short. They need considerably more time than they now have, and I would plead very strongly for a four-year course. I think that this should not be brushed aside with the statement that there is no room. There is no room at the moment, I know, and there is the bulge ; but we must plan a little further ahead and make provision for this as soon as it is humanly possible to do so.

I am always impressed by the Oxford graduates—I am not a graduate of that university myself—who come from the chemistry school and who have had a four-year course. We are talking about use to industry, and they are of far more use than the man who has had three years at any other university. It may be that there has been some pre-selection and that only the best ones go into this fourth year, but these men are of immediate use to the industry ; we do not have to spend so much of the first year or two in teaching them how to apply such knowledge as they have gained at the university. I commend that most heartily to all of you who train physicists for industry. Let them spend a fourth year on some such advanced courses as have already been talked about.

The move which has been made by the D.S.I.R. is a very welcome one and will give us the people that we need. When I speak of the type of people that we really want, may I remind you that we want complete human beings, people who have some knowledge of life and how to get on with others and who can express themselves and write. Perhaps this should be learned at school, but I have the feeling that it is not emphasized sufficiently in the university courses.

I often ask my people how they value the work which they do in industry. I can do no better than repeat what I believe to be Sir Charles Goodeve's maxim, expressed many years ago, on how to evaluate a piece of research work. He said: "The value of a piece of research is the worthwhileness of the objective multiplied by the efficiency with which it is carried out multiplied by the efficiency of the way in which it is written up." There is no need for me to tell you that if any one of those is zero the whole thing is zero. It is worth while remembering that, and I would emphasize that the physicist must be able to achieve every one of those three requirements. He must have the judgement to decide whether or not the work he is setting out to do is worth while. He must have the tools, the knowledge and ability and even the manual dexterity, to carry out the work satisfactorily, and he must be able to report on it satisfactorily.

Mr. E. M. Wareham (*W. H. Sanders (Electronics) Ltd., Stevenage*): The standards of education required in the field of applied electronics are relatively high. Particularly in design and development a weak background is very noticeable. The basic scientific education which goes with an engineering degree at the pass level is rarely adequate, in my experience, to equip the holder for anything more than routine work.

In my company, I supervise an apprentice scheme for student technicians in electronics. In many ways I believe that this is a more satisfactory education and training than a full-time university course to pass level. The course is based upon the National Certificates in Applied Physics which in my area have a pronounced bias towards electronics. I have chosen this course in preference to an alternative in light electrical engineering because I value the more fundamental scientific education which it provides. This type of education is combined with practical training in various departments of the company—not forgetting the production division. In my opinion such a course tends to turn out a holder of a Higher National Certificate in Applied Physics who has a high immediate value to an employer. This is not the case with a university graduate who is regarded as being something of a drag upon his employer's resources for some time.

There is a good deal of useful material in the grammar schools, and some in the secondary modern schools, at General Certificate of Education Ordinary level which might otherwise be wasted were it not for courses of this nature and it is possible that this type of apprentice may also have a potential value as high as the graduate at pass level in many instances.

Dr. A. von Engel (*University of Oxford*): It was stated by Dr. Puls that the chemistry course in Oxford is excellent because it takes four years. This is correct, but in fact it is a three-year course; the fourth year is used to study a small problem under supervision and write a thesis on the subject. I leave it to you to draw your conclusions from that.

Professor R. W. Ditchburn (*University of Reading*): The word specialization is used with different meanings. We are all in favour of some degree of specialization. We all recognize that it is no longer possible for one man to "take all knowledge for his province" but we are all against "excessive specialization." There is no sharp division between those who are in favour of specialization and those who are against specialization. There is, at most, a difference of opinion in regard to the precise position of the boundary between "useful specialization" and "excessive specialization."

Specialization is a process which has been going on for a long time. Long ago there was only one subject—philosophy. When I first became a professor (at Dublin) this subject had been divided. There was a professor of Moral Philosophy and another professor, myself, who was, I suppose, professor of Immoral Philosophy but they called it "Natural and Experimental Philosophy." I was really professor of Physics but the title of the chair went back to a period when "natural and experimental philosophy" included all that we now call physics,

chemistry, geology, botany, zoology and much more.

I believe that the historical process of specialization has not ended and that therefore we must accept new kinds of specialization in the future. In saying this it must appear that I am opposing what Professor Blackett has said but I am not sure that there is any important difference between his view and mine. Having recently been external examiner at Manchester, when Professor Blackett was head of the department, I know his course very well. I think it was just a little more specialized than my own course at Reading. The degree candidate at Manchester was required to take general papers and in addition two papers on special subjects such as cosmic rays, X-rays and crystal structure, etc. The student had to choose two out of five special subjects. I have been considering the possibility of allowing one special subject. Suppose I include " solid state physics " as a special subject—I am sure Professor Blackett will not consider that " excessive specialization "—but if I allow the subject to include certain of the applications to current practical problems—will that constitute " excessive specialization " ? I think not.

I do not believe that most employers are concerned only with their own short term interests but some speak as though they were. They criticize university courses because they do not concentrate on training a man to be immediately useful for specific jobs. They think that they can train a man in their own laboratories better than he can be trained by a postgraduate or Ph.D. course. Now if the object is to make the man immediately useful in relation to a specific problem he should start working on that problem as soon as possible. It is the short-term interest of the employer to have the man well trained in a given problem and little use on anything else. Then, because he is doing useful work he can be paid a good salary and because he would need retraining if he went elsewhere there is less chance of him leaving. Most employers realize that this short-term advantage has to be set against their own long-term interest and against the interest of industry as a whole.

I should like to refer to one experimental course which has been introduced in my own department. We have a general degree, which is modelled to some extent on the Cambridge Part I tripos system. There are some students who pass this general degree qualification in two years and who are not suitable for the theoretical work of the special honours course. Our special honours course is more closely founded on mathematics than that of some universities, and there are students who are quite good practical physicists but who are not up to that course on the theoretical side. For them we have devised a course for a diploma in technical physics. Certain parts of this course are purely mechanical training ; they must do workshop training and glass-blowing. There are also two courses on electronics and on high vacuum technique and there is a special subject chosen for its relevance to the student's interests and to the research projects going on in the laboratory. The students spend about fifteen weeks in the university doing advanced work, and they then spend fifteen weeks in an industrial research laboratory, afterwards returning to the university for another period of about ten weeks before taking an examination. They have to write a report on the work which they do in the industrial laboratory, and the production of a satisfactory account of their work is an essential qualification for obtaining the diploma. The written examination contains detailed questions on the theory that lies behind such things as high vacuum technique. The diploma course is a pass course but I am now thinking of the possible extension of this type of course to a certain type of honours student. Another development which I think is necessary in universities—it may also be helpful to industry, but I am considering it on educational grounds—is the continued education of research students by lectures and discussions in a more active and systematic way than in the past, to bring forward their general knowledge of physics.

Professor J. D. Bernal (*Birkbeck College, London*) : I want to make rather a special point, because I am in a different position

from all the other professors of physics here, in that at Birkbeck we do not concern ourselves with training students for industry since our students are for the most part in industry already when they come to us. Apart from those who are in the teaching profession, most of them are taking the degree of special physics or general physics of London University to improve their qualifications in the jobs which they already hold.

I think that this function is one which deserves consideration by those in industry. Why should you assume that the product as sent from the university is not capable of subsequent improvement ? If this can be done for undergraduates it should be often useful for those who have taken degrees to go forward to take higher degrees while they are still working in industry. There are many firms which release people to take higher degrees full-time in universities, but it is possible at the Birkbeck—I do not know in how many other places it can be done—to take part-time degrees of M.Sc. and Ph.D. while in employment, although it takes longer than for full-time work. I regard this as a valuable possibility.

We also have in London University the completely external higher degree often taken by people working in industry. This has raised quite a number of difficulties, because there is a tendency for the research worker in industry to put in for his Ph.D. a precise report on the job which he is doing for industry. If we allow that to become the rule it might be a way of providing a rubber stamp of approval for what a man is doing, whereas a higher degree has real meaning if the employer is willing to let the research worker look behind what he is doing and get at the principles of the work he is carrying out.

That raises another point which has occupied the university a good deal, namely how far such work can be done without adequate university supervision. A scientific establishment such as Harwell is virtually a university so far as the standard is concerned, so that there is no difficulty there ; but I can foresee the possibility—I do not speak for the university, which I believe takes rather a different view—of university teachers at various grades assisting in part-time supervision of work at industrial research laboratories for external degrees, giving them a much more scientific bent.

I feel that in this way, in addition to improving the quality of the product which we put in, we can also improve the quality of the research worker already in industry, and perhaps keep industrial laboratories more in touch with the developments in fundamental science.

Mr. D. H. Le Croissette (*University of Southampton*) : The title of this conference is " Degree and Diploma Courses in Applied Physics " so perhaps I may emphasize the importance of a problem which has not yet been mentioned. We are concerned not only with the first class honours man, the student who will have no difficulty with any course in physics, but also with the student taking a pass degree or a Higher National Certificate.

I think that the classical physics course—a course based on classical physics with an enphasis on fundamentals—is ideal for the very good man. But we have the responsibility of interesting all the students in the subject. I would like to suggest the injection of a special practical project into applied physics courses. This has been carried out in some universities but is not widespread. This project may consist of a practical investigation in the laboratory lasting for one term or more. The students are given a problem and encouraged to read the literature about it ; they design the experiment themselves and write a report on their work. In this way, we can encourage the students' interest in physics.

Mr. P. Gough (*Brighton College*) : I believe that I am one of only two schoolmasters here. We have been told that it is our job to produce the well-rounded, well-educated person, because it is too late when he goes to the university. I quite agree ; I think it is true that it is our job to broaden the basis of a man's education. I agree also with Professor Ditchburn that our course in physics is probably much too wide for us to

have enough time left to teach everything else that we should try to teach.

The reason why scientists have such a terrible reputation as administrators, and why some people say that they are not well educated at all, is, I think, that those who take up science now are largely people who are extremely eager, as Professor Blackett has said, to do fundamental research. I think that Professor Blackett is completely right when he says that it is a greater number of places at the university which is so important. I do not see how the public schools are going to persuade a boy who is already a great success at Latin or Greek or History or a modern language, who is already fascinated by the humanities, and who is going to be a first-class administrator to deflect his interest in those subjects and turn it into a great interest in science and a career, perhaps, as an administrator in science, or a career in politics. I do not see how it is going to be possible to persuade that boy to deflect his attention, when he is obviously going to get a first-class scholarship to the university, and all the masters who are teaching him want him to get such a scholarship. If he were to take up science he might very easily not get into the university at all, because there might not be room for him. The problem which Professor Blackett has mentioned, of providing more room at the universities, is therefore fundamental, because I do not think we shall ever persuade half the boys with the best brains at the public schools to take science unless they are fairly certain of being able to get a scholarship in it to the university. It is those boys, who will always be interested in the humanities and have the brains to be good scientists, who would be of real use in industry, and, for that matter, in administering the whole country.

I should like to refer to an institute in the United States of America called the Battelle Institute, which seems to me to fill a gap which a great number of speakers have mentioned. It is an institute for industrial research, a centralized institute endowed for the purpose, in which graduates are able to do experiments for different industries which place their orders with the institute. It seems to me to provide a possibility for training people to be interested in what industry needs, and to do more or less fundamental research. We have heard that the Ph.D. does not necessarily fit graduates for industry, and I think that many university men are not particularly pleased with the way in which industry educates and specializes the graduate ; but a modification of the Battelle Institute, a half-way house, might be very inspiring to university scientists and would be of the utmost use, I imagine, to industry.

There is the great advantage of pooling results in this huge institute. There is not so much industrial secrecy, at any rate in the institute itself. A graduate can move from department to department and get a much wider grasp of industrial applications than any one firm could conceivably give him, while at the same time industry reaps its reward, because the men working there, more or less in a university atmosphere, should be able to produce far better results than a man working on his own and not knowing what is going on in other industries similar to his own.

Mr. R. B. Webber (*Cambridgeshire Technical College and School of Art, Cambridge*) : There is one aspect of this problem which seems so far to have been a little overlooked, and that is the relative roles that the universities and the technical colleges are taking and might be expected to take. Many speakers have shown that the types of physicist that we require in industry and in Government service are not limited to one. We need first-class research workers, we need highly qualified people on the development side ; and we need scientists who are good administrators. We also need large numbers of scientists.

The aspect of the problem which seems important to me is that we have a few universities and a large number of technical colleges. Perhaps the universities can cope with two or three of the types of scientist required, while the technical colleges may be able to deal with the rest. I should not like to see the universities a great deal larger than they are at the moment, because, from what I have

been given to understand, many of the people who do get there on open scholarships do not come up to expectations. That may well be due to selection difficulties. However, it shows that there may be a very large number of potential scientists who are not quite worthy of university education but who might be given something much simpler and perhaps more specialized, or more technical at any rate. The technical colleges could, with a little reorganization, and if given a little more scope, provide what is wanted for that group, which is certainly a very large one.

Much has been said about the people who are taught, but one very big aspect of the problem is the people who do the teaching. There are not enough of them, and those who are coming into the teaching profession are not always quite what one would like to see. I should hate to see industry and Government service becoming so attractive that none of the cream ever went into education. Some encouragement should be given in that direction.

Dr. E. Robinson (*English Electric Co. Ltd., Stafford*) : More and more the discussion seems to be getting away from the point of this conference, largely, I think, because there is rough agreement that an honours course in pure physics affords the best grounding of all, but that the final product of such a course is not suited to the immediate use of industry. As to increased numbers of such graduates, this, I believe, is our prime necessity at this moment. Professor Blackett's plea was for larger numbers. A later speaker suggested that this will be to the detriment of the quality of the graduates. I do not think that this follows at all, and I do not think that Professor Blackett intended to imply that to introduce more graduates need necessarily involve a sacrifice of standards.

I have in mind that industry itself ought to be able to help in giving the degree of experience which we require in graduates these days, in view of the fact that we cannot possibly at the present time get a four-year course in an honours school. It should be possible, I feel, for industry to offer a kind of postgraduate sandwich course, similar, perhaps, to the Harwell reactor school. It is a very great reflection on our educational system at this moment that in industry if we take an honours graduate and want him to do nuclear research or something to do with atomic power we have to try to get him into Harwell to get the necessary background.

Mr. F. I. L. Knowles (*Armament Research and Development Establishment, Fort Halstead*) : I should like to make two or three points, with over simplification and some exaggeration. I agree with Professor Blackett on at least one thing, and that is that fiddling with curricula will not meet out great need for physicists. But what is our need for physicists ? Is it for technologists or for what are called fundamental physicists ? In my opinion there is only one answer : it is for plain physicists with a sound and broad knowledge of the essential aspects of physics, which were emphasized this morning in the opening addresses. We do not want—and I speak particularly now for Government service—people with a vast array of industrial technologies, nor do we need people with a vast array of Professor So-and-So's and Professor Somebody-Else's technology for determining a meson track. I suggest that the universities have allowed a large number of their junior research students to study techniques rather than physics, and that they are in many instances in quite as bad a case as industry itself. I would strongly urge that what we need is just good capable physicists.

What is the problem in front of us in providing them ? I think that difficulty arises at the very beginning of our educational system. I discussed it this morning with a well-known headmaster and he agrees with me, but he thinks that the schools are hamstrung by examination syllabuses and can do little about it. My ten-year old daughter was last week learning about square perches. It would be better for her to learn about Angstroms because there is a chance that she might use them, but who will use a square perch, and how many people even use a chain ?

It seems to me that in the school we have to teach the very fundamentals of good, sound physics, with just such detail and illustration as is necessary to make the subject live.

A few years ago, I was recruiting scientific assistants on three criteria only : (i) could the man operate the ordinary simple processes of logarithm ; (ii) did he know Ohm's law ; (iii) had he a reasonably presentable appearance. It was the only basis on which it was possible to recruit at that stage. The majority have done well. I would far rather take on a man with a sound knowledge of Ohm's law and of similar laws dealing with magnetism and a.c. theory and so on, than a man who had a sort of B.B.C. television knowledge of a wide variety of new scientific techniques. The answer is, I suggest, right from the early stages to prune the syllabus of redundant repetitive material, often of long-lost interest, leaving what is necessary to a clear, live understanding of the subject and its relation to the whole body of physics.

Professor J. S. Rankin (*Royal College of Science and Technology, Glasgow*) : I think that the question which we have to face is this. We are thinking of whether or not the present day physics course should be altered slightly to make it suitable for industry, and in the next breath we are saying that we cannot do that, that we must keep the courses as they are, that they are excellent, that they have been like that for a hundred years. That is not a proper approach. What we have to ask ourselves to-day is this : do we require another type of technologist in industry ? My answer is decidedly " Yes." After all, 45 years ago the chemist found, or somebody found, probably an industrialist, that the output of the universities of pure chemists did not satisfy the need, and decided that there should be a different type of training, and brought in the technical chemist or the applied chemist. We started that in Glasgow 45 years ago. I do not know when it started in England ; possibly a little later !

If Professor Blackett is correct, the chemists in the universities 45 years ago should have said : " No. We are doing fine. We will just give them another year and make them applied chemists." But why should the chemist, or any other scientist, have to do an extra year in college or university if he is going into industry, when other technologists do not have to do so ? Must they do so ? I do not think so. For the last thirteen years I have been suggesting that in industry to-day we have this gap. We have the pure physicist and we have the engineer, but there is a missing link which we have to provide.

I do not suggest that I know the answer, but I am doing my best. I started a course eight years ago in applied physics and it is doing exceedingly well, but that is by the way. What type of training should they get ? I ought to have mentioned that other people besides myself have noticed the same need. In 1948 Sir Henry Tizard, who was then President of the British Association, mentioned that at that time there was a need for the application of the findings of science in a quicker way in industry, and in the following year the Hankey Committee reported that in industry there was a need for the pure physicist, but that there was a greater need for a man who was described as a physicist-engineer. I agree with that.

The only point of difference between myself and Professor Blackett is, I think, on the way in which we should arrive at that. I claim that we can do it in a course of normal length, and we are doing it in Glasgow. We have already had four sets of students turned out, and we have an average of forty to fifty students every year studying applied physics. Last year fourteen were turned out, and we have an annual input of fourteen or fifteen, even though the course is not extensively publicized. In spite of what has been said about not needing this and that, and simply offering a normal physics course, the question is, what does industry want ? Is industry entirely happy about the present output ? We have had one or two people here saying " Yes," but that may be because they have not had the experience of anything else.

In my talks with industrialists in Glasgow, they seem to like our type of training. In

fact, a significant point is that several engineering concerns in the Glasgow district who had never in the whole history of their existence employed a physicist are now wanting to employ our applied physicists. Why did they not employ them in the past ? It was a luxury for some of them. They are not all big firms with fifty million pounds of capital who want men to improve things for them in twenty years' time ; they want things done now.

It is gratifying to me to know that we can get our youths employed in Glasgow. They used to drift down to the south, especially the physicists, to get into industry, but there is now, I believe, a drift the other way, or at any rate the drift southward has lessened. One English firm has sent a youth in their employ to take our applied physics course.

In my view it is important to note that we do not aim to turn out the same type of physicist as the universities. We do not claim to turn out fundamental physicists ; that is the province of the universities. The course is based on the sandwich system. Students take some classes in the electrical and mechanical engineering departments, the idea being to develop one who is partly an engineer as well as a scientist and so when he enters industry, he understands the language and methods of the engineer. The question is : are they actually in demand ? My answer is definitely " Yes," as I cannot supply them in sufficient numbers.

Dr. A. Harvey (*College of Technology, Cardiff*) : I should like to follow up a remark made by Mr. Knowles, who said that all that is required is a good straight physicist. Professor Rankin has also touched on the question which I wish to raise—which is: What is the role of the technical college to be ? Everyone talks about the shortage of scientists and technologists, the cry is that we are scraping the barrel and do not know where the extra people are to come from. On the engineering side, the introduction of sandwich courses is tapping a new layer of talent. We are finding that many pupils get tired of school and academic work at about the age of sixteen and want to get to grips with a job. So they leave school and become apprentices, coming up " the hard way " by means of the national certificate scheme. By the time they are eighteen or nineteen, with two or three years in industry behind them (where they have followed the course of the raw material until it becomes the finished product, where they have seen the machines and instruments in actual use which were formerly only pictures in textbooks), they seem to get an academic second wind and they realize that there may be something in an academic training.

They are therefore coming to us for these sandwich courses in engineering. British experience of them goes back some fifty years on a small scale ; on a big scale we have only a few years' experience but I have been surprised, as an academic physicist, to see the type of material that we are getting. It is going to be most useful to the community from the point of view of production engineering. It won't include much of the high-flying research type, but it will turn out the type of engineer who is going to be very useful on the production side.

The question that I want to ask is this. We are told that all that is wanted is the good straight physicist, but has industry any need whatever for a production physicist of a similar type, and, if so, where is that production physicist to come from ? It is not the job of the universities to turn out such men, any more than it is the job of the technical colleges to try to turn out the pure academic physicist. If we are to do this job of turning out production physicists, how are we to start ? On the engineering side the lad goes into industry at sixteen, takes up an apprenticeship, and then comes back to us at the age of eighteen or nineteen. Where are the similar lads on the physics side ? They may go at sixteen as laboratory technicians, but, apart from the applied physics national certificate scheme, what chance have they to come forward to us at the age of nineteen ? We are very concerned in the technical colleges about this problem, feeling that it is a job which we should be doing, but we do not know where the students are to come from. But does industry agree that there is a need for a production physicist ?

Mr. F. I. L. Knowles (*Armament Research and Development Establishment, Fort Halstead*) : I am well aware of the sandwich course and I welcome it very much, but I was dealing with the university degree people. I would offer this challenge. Much of the university teaching is rather allied to old-fashioned botany, and I should like to see good horticulturists. It is much harder to coerce nature than to observe her ways.

Sir George Nelson : We have now reached the time when you would like to hear Professor Blackett reply to some of the questions, but, before I ask him to do so, I wish to make a few remarks myself, not in my capacity as Chairman, because as Chairman it is not my business to sum up this discussion, but because I happen to have a great interest and to have played a great part in the establishment of many research establishments in my own organization. I can therefore make some comments with that background experience.

Professor Blackett said to start with that he felt he had no outstanding change to suggest. I think that that is an extremely wise remark, because from an experience of dealing with a very wide range of qualified people of all classes—physicists, engineers, mechanical and electrical, metallurgists, chemists and mathematicians—I quite agree with him that it would be very difficult to give a generalization on this subject. In the main I would say that a very good job is done, but obviously it is always possible to improve, and, if I may say so, my belief at the moment is that it is necessary to give some attention to the choice of the people who take these courses. Not only must they be, if they are coming into industry, men of highly qualified character in their particular field, but they must also be men of character themselves. An outstanding recommendation that I should like to make to universities and technical colleges is that in selecting your students you should not choose them purely on the basis of their ability to pass your entrance examinations ; do make a study of their personal qualities, which play, as I shall mention in a moment, an important part in their work in after life.

I had not seen the D.S.I.R. grants to students to give them the opportunity to take courses apart from research, but I think that that is of immense importance and I hope that great use will be made of it. I was interested in Professor Blackett's reference to the Barlow Committee. I felt very privileged to serve with him and others on that Committee, and I feel that it is a great credit to the universities that they dealt with their side of it so ably ; but I deplore the time taken to deal with the technical college courses by the Percy report, because we must have proper support all the way down the line for the highest scientists in the performance and development of the work with which they are associated.

I endorse to the utmost Professor Blackett's remark that the basic general courses should be in pure scientific training in the universities before specializing. In the fields with which I am concerned, which are very wide, covering hydrodynamics, thermodynamics, electricity, radio communications, electronics, aerodynamics, guided weapons, computers and fundamental physics, I find that there is a tendency for entrants to universities to follow the studies of the glamorous fields—atomic energy, the science associated with radiocommunication, with guided weapons and so on—and we can always get men for those fields ; but, while I do not want for one moment to detract from the enormous importance of atomic energy to this country, at the same time we must have a full supply of the old classical physicists, who have to deal with all the problems which arise in these fields. We want pure scientific training in basic principles, and training of the highest character.

Professor Blackett did just touch on military service. I think that the question of military service exemption is a fundamental part of the solution of this problem. In Russia, for instance, all the people taking scientific courses are exempt, not just during the course but for ever, from military service.

Professor Blackett referred to the question of how do we in industry use our scientists. I must say that that is a matter which disturbs me very considerably. It is all very well

to talk about increasing the supply of physicists and other scientists, but we have a great number of them available even to-day, and I am perfectly satisfied that we are not making the most efficient use of them. It is a problem for industry and it is a problem for the research associations and a problem for Government research and development bodies. There is an immense field, in my opinion, for improving the efficiency of the use that is made of scientists, quite outside the question of providing more, which we must do in the future.

Professor Blackett's remark about the difficulty which some scientists have in settling down in industry is a very fair comment, but I must say that that is not always industry's fault, though I agree that it is in some cases. When I joined my present organization the equipment and so on and the support that was given to scientists were quite inadequate. To-day these departments have plant and equipment and instruments of the highest quality and every effort is made to meet their needs. There are a great many companies and industries in this country which make that type of provision, though there are unquestionably some which do not, and they will have to suffer, because the demand now exceeds the supply, and if these inadequately equipped industries with their needs for research and development wish to keep pace with the needs of this country and maintain their own position in supplying those needs they will have to rectify that position. We must in industry tackle that question, and I think it is a good suggestion that at some time a conference should be held on the subject.

Professor P. M. S. Blackett : I am sympathetic towards the idea of applied physics courses in the sense of a straight physics course with a *slight* bias towards some local or special interest or particular technology, provided it is not forced to be too narrow, so that the student going into it does not get a broad education. I like variety, and I think that different types of courses at different universities and technical colleges, etc., all have their parts to play. Do not let us all try to do exactly the same thing. When I spoke against applied physics courses, I was speaking against them as things artificially grafted on to main university departments in order to train people more directly for industry.

I should like to take the opportunity to apologize to Dr. Puls for upsetting him. I am sorry that I made him angry, because I thought that I, for once, was being exceedingly orthodox and was merely paraphrasing the last sentence of the new report on scientific and engineering man-power in Great Britain. This has just been issued by the Office of the Lord President and which is the equivalent of a new Barlow Report : with the important difference that it has not been acted on yet. It is there stated that over the next ten to fifteen years we should aim at an annual figure of graduations in pure and applied science of about 20,000 as against 10,000 to-day.

Of course, I was aware of the problem of maintaining standards. However, I believe that the reserve of ability in the country is likely to prove adequate to get these additional students. These fears for standards go back to the time of the Barlow report. Many of my more pessimistic scientific colleagues said at that time that the recommended expansion could not be carried out because there was not the ability in the country. Experience has shown that this was not true. It is, of course, not statistically proved that if we go from an output of 10,000 to 20,000 we shall not have to scrape the pot a little. I feel we must certainly get this extra output whether we have to or not.

With regard to the possible introduction of a general four-year course, we must face the fact that it is going to be very expensive, and unless we realize this we shall fail to do it. A general fourth year would add 33 per cent to the total numbers of students in residence. The cost of university and college building is such that it would cost hardly less than £3,000 of capital expenditure on building and equipment to house one additional student : this gives roughly £10,000 for an output of one student a year taking a three-year course. If plans to double our output of

scientists are going to be carried out, this means an additional output of 10,000 students a year and so, for a three-year course, an additional 30,000 places. At £3,000 per place this means a capital cost of £100 million for buildings and equipment.

If in addition we add a general fourth year, the total number of places in the universities and colleges for science and engineering students will have to rise from 60,000 to 80,000. The additional 20,000 places will cost some £60 million in capital.

These figures may be on the high side as they assume, of course, that there is little unused and so available space for expansion in existing university and college buildings. There was such available space in 1946, otherwise the Barlow doubling could not have occurred. There is probably not much unused available space left now in the universities but there may be an appreciable amount in some technical colleges.

There is one additional point of importance which must be made. The above calculations are based on the assumption that if the number of students in residence in the universities increases, the number of staff, research students and research facilities increases in the same ratio. This seems to me an essential requirement for a healthy expansion of science and technology at the universities.

Mr. O. W. Humphreys expressed the warm thanks of the meeting to Sir George Nelson for his chairmanship.

News of Members

FELLOWS

N. F. Astbury takes up an appointment as Deputy Director of the British Ceramic Research Association on May 1, 1957.

Professor W. T. Astbury has been elected a Foreign Member of the Swedish Royal Academy of Sciences.

R. Beeching has been appointed to the Main Board of Imperial Chemical Industries Ltd.

G. Black has recently taken up an appointment as Principal Scientific Officer at the Research Department, United Kingdom Atomic Energy Authority, Risley, Lancashire.

F. P. Bowden has been awarded the Rumford Medal of The Royal Society.

J. R. Bristow has become Senior Lecturer in Applied Physics at Cardiff College of Technology and Commerce.

J. E. Caffyn has taken up an appointment at Northampton Polytechnic, London.

Sir John Cockcroft has been awarded the Kelvin gold medal for 1956, by The Institution of Civil Engineers.

W. S. Elliott has joined I.B.M. World Travel Corporation in London.

D. H. Follett has been appointed Keeper of the Department of Electrical Engineering and Communications, the Science Museum, London.

A. Harvey has been elected President of the Association of Principals of Technical Institutions.

J. W. Illingworth is now Director of Research of the Hosiery and Allied Trades Research Association.

L. Jacob is now at the Royal College of Science and Technology, Glasgow.

W. A. Jennings has returned to the Royal Northern Hospital, London, after a year at the Argonne Cancer Research Hospital, University of Chicago. He has been awarded a Diploma in Radiological Physics by the American Board of Radiology.

K. C. Lang has left Australia to become Physical Sciences Representative of the Australian Department of Supply, Australia House, London.

H. Pelzer has moved to the Electrical Research Association Laboratory at Leatherhead.

R. W. Pringle has returned from Canada to take up an appointment with Nuclear Enterprises (G.B.) Ltd., Edinburgh.

G. de Q. Robin has joined the Department of Geophysics, Australian National University, Canberra, as Senior Fellow.

J. Savage has joined the Board of the Continuous Casting Co. Ltd.

H. G. Taylor has been appointed Director of the Electrical Research Association. The appointment will take effect from April 1, 1957.

R. S. Tebble has joined the Physics Department of the University of Sheffield as Senior Lecturer.

H. Winogradoff is now in America with the Research Division of Philco Corporation.

A. J. Woodall has recently become Associate Professor of Physics, Royal Military College of Science, Shrivenham.

ASSOCIATES

N. L. Allen is now a Research Physicist in the Research Laboratory of Associated Electrical Industries Ltd., Aldermaston.

S. Bingham is a lecturer at the City of Liverpool College of Building, Liverpool.

D. C. Bisset is now a technical officer with British Nylon Spinners Ltd.

P. G. Black is now a lecturer in the Department of Physics, University of Birmingham.

J. G. Brown has taken up an appointment as a lecturer at the Royal Technical College, Salford.

P. F. Burden is in the Research Department of English Rose Ltd.

C. C. Butler has been appointed to a University Chair of Physics tenable at the Imperial College of Science and Technology.

J. D. Coleman has been promoted to Principal Scientific Officer at the Road Research Laboratory.

J. H. Coupland has joined the Atomic Power Department of the English Electric Co. Ltd. at Whetstone.

J. K. Donoghue has taken up a post as physicist to the Medical Research Council Group at the University of Sheffield.

G. K. Eaton has moved from Redhill to the Mullard Southampton Works.

R. C. Faust is now with the British Nylon Spinners Ltd.

W. Fulop now works for Hivac Ltd., Harrow, Middlesex.

J. J. Gameson is at the Atomic Weapons Research Establishment, Aldermaston.

I. A. Gatenby is working at the Royal Australian Naval Experimental Laboratory, Sydney, Australia, where he expects to stay for the next three years.

J. H. Hodgson has taken up an appointment with the Mullard Radio Valve Co. Ltd.

T. A. Holbeche has moved to the Aerodynamics Department of the Royal Aircraft Establishment, Farnborough.

A. E. Horsfield is now with the Research Station of B.X. Plastics Ltd., Essex.

L. R. Hulls has joined the Application Engineering Department, District Apparatus Division, Canadian Westinghouse, Ontario.

A. H. M. Hytch is now employed by the United Kingdom Atomic Energy Authority at Risley.

D. Jakeman is now in the Physics Department of the University of Birmingham.

V. J. Jehu has been promoted to Principal Scientific Officer, Department of Scientific and Industrial Research.

H. Jenkins has recently become a lecturer in physics at the Mid-Essex Technical College, Chelmsford.

W. F. Kilby has been appointed Head of the Textile Physics Section of British Celanese Ltd., Luton.

J. McCrickard is joining the Operations Branch of the Industrial Group of the United Kingdom Atomic Energy Authority.

J. P. Morrison has joined Aircraft Marine Products (Great Britain) Ltd. as a Research Physicist.

K. P. Nicholson has taken up an appointment with the Australian Atomic Energy Commission in Sutherland, New South Wales.

P. H. Oliver is now Laboratory Manager of the Experimental Department, Courtaulds Ltd., Rochdale.

B. Pickup has taken a post with the Anchor Chemical Co. Ltd., Manchester.

C. B. Richards has joined the Department of Colloid Science, University of Cambridge.

R. C. Ritchie has recently taken up an appointment as a research physicist with Tube Investments Research Laboratories, Cambridge.

G. S. Rose has joined the Surface Physics Section of Associated Electrical Industries Ltd. Research Laboratory at Aldermaston as a research physicist.

L. R. Shepherd has been elected President of the International Astronautical Federation for the coming year.

C. A. Skinner was recently appointed Head of the Department of Mining and Engineering and Vice-Principal of the County Technical College, Worksop.

D. C. G. Smith has been attached to the Research and Development Branch of the United Kingdom Atomic Energy Authority, Dounreay.

J. Stockill is now Senior Physics Master at Henry Smith School, Hartlepool.

J. W. Sturgess has been appointed lecturer in the University of Manchester.

H. W. Taylor is now in charge of the Non-destructive Test Section of Kelvin & Hughes Ltd., Barkingside.

T. C. Toye is now a lecturer in Physics at Swansea Technical College.

E. W. Voice is Head of the Chemistry Department of the British Iron and Steel Research Association.

D. B. Watt has been appointed Works General Manager of British Hydrocarbon Chemicals Ltd.

B. M. Wheatley has been appointed Health Physicist at C.E.R.N. He is now in Geneva.

J. C. Williams has joined the Billingham Division of Imperial Chemical Industries Ltd.

G. W. Wilson is in charge of the Metal Physics Section of the Metallurgy Department of the Hawker Siddeley Nuclear Power Co. Ltd.

B. Wood is now senior lecturer in science at Watford Technical College.

D. Wroe has joined the Iraq Petroleum Co. Ltd. and expects to be abroad for some time.

GRADUATES

J. Adamson is now a member of the staff of C. A. Parsons & Co. attached to the Atomic Energy Research Establishment, Harwell.

Miss A. M. Borland is now Mrs. K. Gilson.

K. Canfor is now employed by the Canadian Westinghouse Co. Ltd., Hamilton.

P. Charsley has obtained a post as a Research Physicist with Associated Electrical Industries Ltd., Aldermaston.

G. I. Crawford is working for Vickers-Armstrong (Engineers) Ltd., and has been attached to the Naval Section at Harwell.

E. B. Dickinson has been appointed physics master at the Wanganui Collegiate School, New Zealand.

E. W. Dickson was recently appointed research physicist at Tube Investments Research Laboratories, Essex.

G. T. Dove has joined the scientific staff of the General Electric Co. Ltd. at Wembley.

F. J. Fayers has joined the Californian Research Corporation of the Standard Oil Co. of California.

K. Fitch has taken up an appointment as lecturer at the Birmingham School of Technology.

N. Gibson has joined the Technical Optics Section of Imperial College of Science and Technology.

R. W. Goodley joined the Mosul Petroleum Co. Ltd., in January. He is now in Iraq.

D. I. James is working with the Research Association of British Rubber Manufacturers as a research physicist.

A. A. Johnson is now a research assistant in the Department of Physical Metallurgy, Imperial College of Science and Technology.

A. B. Lewis has joined the British Cotton Industry Research Association.

M. S. Lewis has been transferred to the Proof and Experimental Establishment, Pendine.

A. C. Loader has joined the Science Department of Reading Technical College.

I. M. Mitchell has moved to the Mullard Southampton Works.

T. P. Moorhead has taken up a post as Experimental Officer at the Atomic Energy Research Establishment, Harwell.

E. Morrow is now employed by the United Kingdom Atomic Energy Authority as a scientific officer.

F. D. Morten has been transferred to the Mullard factory at Southampton.

P. W. Noakes has taken up an appointment with the British Scientific Instruments Research Association, Chislehurst.

F. Paton is now with the British Thomson-Houston Co. Ltd., Rugby.

H. Ridley is a research physicist with James A. Jobling, Sunderland.

I. F. Rolls has been appointed Head of the Science Department of Tulse Hill School, London.

H. C. Rose has taken up an appointment with the Central Electricity Authority Research Laboratories, Leatherhead.

G. Rowlands has been awarded a Post-Doctorate Research Fellowship tenable at the National Research Council, Canada. He is now in Ottawa.

N. H. Saunders is now a research demonstrator in physics at the University of Sheffield.

L. N. Snell is working for C. A. Parsons & Co. Ltd., Newcastle, on behalf of the Nuclear Power Plant Co. Ltd., Cheshire.

D. E. Taylor has recently taken up an appointment with the Field Investigation Group of the National Coal Board.

G. M. Thomas will be in the Antarctic until April, 1959.

T. L. Watkins is now a research assistant at the Borough Polytechnic.

D. Weatherley is on the staff of the High School for Boys, Middlesbrough.

R. Wilcox has recently joined the Research Department of Imperial Chemical Industries Ltd. Metals Division, Birmingham, as a Technical Officer.

J. Zarzycki is now an assistant lecturer at the Borough Polytechnic.

The Institute's Journals

PRINCIPAL CONTENTS OF THE MARCH, 1957, ISSUES

Journal of Scientific Instruments: Volume 34, No. 3

SPECIAL ARTICLE

A survey of image storage tubes. By H. G. Lubszynski, F.Inst.P. (*Electric and Musical Industries Ltd., Hayes, Middlesex*).

There are two types of half-tone storage tubes. They operate either with charge restoration or charge modulation. After stating the requirements such tubes must fulfil for various applications a number of tubes, representative of their classes, are described. The factors limiting their performance are discussed. In general writing speeds of O.I. as μs/picture element can be achieved, while reading times may vary from a fraction of a second to many hours. Limiting resolutions range from 400 to 2,000 lines across the target. Erasure times are still somewhat too high for use in ordinary television. Calculations indicate that improved performance and sensitivity may be obtained in a photoconductive storage tube by incorporation of an electron multiplier. A special type of charge modulation tube is the direct viewing tube which allows observation of the stored picture directly on a fluorescent screen in the tube. Finally a number of applications of such tubes are described.

ORIGINAL CONTRIBUTIONS

Accessories for measuring circular dichroism and rotatory dispersion with a spectrophotometer. By S. Mitchell (*Chemistry Department, University of Glasgow*).

Cotton effect studies require data on absorption, circular dichroism and optical rotation, and it is convenient to obtain them all with the same instrument. The apparatus now described makes this possible over the wavelength range 3,500 to 10,000 Å.

The calibration and use of an air-driven ultracentrifuge. By P. Johnson (*Dept. of Colloid Science, University of Cambridge*).

The operation of a commonly available (Phywe) type of air-driven ultracentrifuge is discussed, with particular stress upon those experimental aspects which affect the accuracy of derived sedimentation constants. The use of a thermistor in a simple bridge circuit and its calibration by the melting of diphenyl ether to give the actual temperature of the ultracentrifuge cell is described. The derived correction is found to be constant over a considerable range of values of the rotational

speed and of hydrogen pressure, but it is strongly dependent upon rotor-thermistor distance. There is good evidence that the thermistor keeps pace with changing rotor temperature. A considerable measure of agreement between the sedimentation constants derived on the basis of the above calibration with those obtained from Spinco values after correction for the adiabatic cooling of the rotor is shown. Attention is drawn to the use of a ball bearing in the base of the rotor which is the probable cause of the unduly large increase in rotor temperature during normal operation.

An improved micro-electrophoresis electrode assembly for use in micro-biological investigations. By D. E. E. Loveday and A. M. James (*Chelsea Polytechnic, London*).

In the assembly described the electrode liquid (potassium chloride solution) is separated from the suspension under investigation by a sintered glass disk (instead of a plaster plug) and this results in a more permanent and reliable apparatus. The apparatus can be used at higher field strengths than was previously possible, thus enabling low electrophoretic mobility values to be accurately determined. Results obtained are in good agreement with those reported in the literature.

Experimental investigations of the dead time of univibrators. By D. Kiss and J. Szivek (*Central Research Institute for Physics, Budapest*).

In a series of measurements carried out on several types of plate-to-grid-coupled univibrators (mono-stable multivibrators) triggered by negative pulses it was found that the dead time strongly depends on the amplitude of the triggering pulse. It has been proved experimentally that this effect leads to time lags if the univibrator is triggered by pulses of a Geiger-Müller counter.

An improved technique for the measurement of contact potential differences. By K. A. Macfadyen, F.Inst.P., and T. A. Holbeche, A.Inst.P. (*University of Birmingham*).

A development of the vibrating-condenser method is described. It is used for the measurement of contact potential differences between a standard electrode and an area of about one square millimetre of a metal surface immersed in an insulating liquid. Discrimination against circuit noise is achieved by homodyne rectification. A novel form of drive for the vibrating-condenser is used. Contact potential differences may be measured to an accuracy of 0·1 mV.

Improving the linearity of barrier-layer photocells. By D. G. Wyatt (*University of Oxford*).

A modification of the Campbell-Freeth circuit is described, whereby the effective series resistance of a barrier-layer photocell, in so far as it is constant, may be eliminated. The results suggest that the series resistance includes part of the barrier-layer.

A soft valve scaler for intermittent fast counting. By G. W. Hutchinson (*University of Birmingham*).

A simple scaling circuit is described in which gas-filled scaling valves are used for counting bursts of radiation without severe counting losses, even when the mean interval between counts within the bursts is much less than the resolving time of the soft valves. To do this, information is stored during the bursts as charge on a condenser and is subsequently read off as a series of evenly spaced pulses by discharging the condenser with a standard repetitive waveform.

An apparatus for investigating the low-pressure oxidation kinetics of hot metals. By L. G. Carpenter, F.Inst.P., and W. N. Mair, A.Inst.P. (*Royal Aircraft Establishment, Farnborough, Hants*).

An apparatus is described for measuring, by a continuous flow technique, the sorption of gas by a hot metal filament. The method is applicable to cases such as the oxidation of titanium in which sorption is so rapid that the " closed volume " technique cannot be used. It has the advantage that the accumulation of impurities in the reaction vessel is avoided. The data of a typical titanium oxidation experiment are given, together with a discussion of accuracy and sensitivity. The apparatus, which includes a simple manostat, is of general suitability for continuously introducing a metered gas flow of the order of 10^2 μl/min into a low pressure system. The same apparatus may be used with closed volume technique for metals such as gold, which react very slowly with oxygen.

An extensometer microscope stage for photo-elastic studies in rubber. By E. H. Andrews (*The British Rubber Producers' Research Association, Welwyn Garden City.*

The instrument described is designed for attachment to the stage of a polarizing microscope in place of the conventional mechanical stage. Its purpose is to permit the use of a special compensator technique to determine stress distribution at the tip of a tear in an extended sheet of rubber.

Examples are given of the stress distribution, both in magnitude and direction, at the tip of a tear in pre-vulcanized latex sheet, and the relative behaviours of the two principal stresses briefly discussed.

A system for controlled linear cooling of laboratory furnaces. By T. W. Lomas and L. G. Finch (*Hadfields Ltd., Sheffield*).

A synchronously-driven resistance bridge network has been developed which, when used with a suitable proportioning temperature controller, will control linearly the heating or cooling of a small laboratory furnace within the range 6 to $\frac{1}{16}$°C/min. The theory and design of the unit are described.

British Journal of Applied Physics: Volume 8, No. 3

SPECIAL ARTICLE

Some recent developments in the physics of fuel combustion. By M. W. Thring, F.Inst.P. (*University of Sheffield*).

The main factors limiting combustion intensity in practical solid or liquid fuel systems are macro and micro mixing of fuel and air, heating the incoming fuel and heat loss from the flame. Micro mixing leads to a combustion time proportional to the square of the initial particle or droplet diameter so that fineness of grinding or " atomization " is the prime essential. In grate firing the high relative velocity of gas and particle can give a much greater rate of micro mixing and the particles remain in the combustion chamber until they are consumed. Macro mixing can be predicted from isothermal models in the three cases of the high velocity fuel jet, the large preheated gaseous fuel jet and the low Reynolds number heating flue—the geometrical distortion to allow for the density change on combustion is different in the three cases. The first case which corresponds to the liquid fuel fired open hearth steel-melting flame has been extensively studied to throw considerable light on the optimum design. Models can also be used for predicting the erosion of walls, the distribution of fuel residence times and the effect of buoyancy. A method of calculating the heat transfer rate from various flames in the open hearth furnace is providing a link between the model work, and flame radiation measurements and practical operation.

CONFERENCE REPORT

Summarized proceedings of a symposium on thin films. Reading, September, 1956.

The Electronics Group of The Institute of Physics held an informal symposium on thin films at the University of Reading on September 28 and 29, 1956. The papers presented are summarized in the report.

ORIGINAL CONTRIBUTIONS

The measurement of peak voltage using a cathode-ray tube. By Eric S. Fairley (*The Royal College of Science and Technology, Glasgow*).

The voltage to be measured is applied across the primary of a standard potential transformer and the secondary voltage, at approximately 110 V, is balanced against a direct voltage, using a cathode-ray tube as a null indicator. The direct voltage is measured accurately using a suitable potentiometer and volt-ratio box. Using a cathode-ray tube specially developed for this particular application an accuracy of better than 0·15% may be readily obtained. An alternative arrangement, in which the potential transformer is replaced by a suitable high voltage resistor divider, is described.

A method of measuring the shear modulus of thin xylonite sheet. By J. Clarkson (*Naval Construction Research Establishment, Dunfermline, Fife*).

A torsion balance is described, in which a common torque is applied to narrow strips of steel and xylonite connected end to end, and the twist of each specimen is measured. Knowing the shear modulus of steel, its twist gives a measure of the torque, and the shear modulus of the xylonite may then be calculated from its rotation. The measurements throughout are very easily made, and they do not depend in any way on frictional forces, nor are any forces applied to the specimens apart from the end forces producing the torque. These features are particularly important for thin xylonite which has very small torsional and bending stiffness.

Short duration discharges between separating contacts in a 6 volt circuit. By J. Riddlestone (*The Electrical Research Association, Leatherhead, Surrey*).

Records of arc voltages of very short duration between separating contacts have been obtained with the Electrical Research Association ultra-high-speed oscillograph. The contacts used were of platinum, palladium and silver. The closed circuit currents were 4·5 and 8 A for platinum and 4·5 A for palladium, the circuit inductance ranging from 0·07 to 4·7 μH. Representative records and a tabular analysis of their important characteristics are given. Discharges occur under all conditions covered in the experiments, their durations varying from about 0·01 to 1·0 μs. Voltages are low, in some cases as low as 7 V, but usually lying within the range 10–18 V. It is shown that there is insufficient evidence as yet on which to base a theory of the arc at separation or a relationship between transfer and arc characteristics.

An extraction replica method for large precipitates and non-metallic inclusions in steels. By G. R. Booker, A.Inst.P., and J. Norbury, F.Inst.P. (*Richard Thomas and Baldwins Ltd. and Steel Co. of Wales Ltd., Whitchurch.*)

A replica method is described which enables large (up to 10 μ or so) precipitates and inclusions to be extracted from steels. There is no etching through the replica, and consequently weakening and staining of the film are avoided. In addition to more stable constituents, included material normally dissolved by bulk extraction methods has been successfully extracted. Examples of the extraction of iron nitride, iron carbide, and non-metallic inclusions are given.

Highly-conducting gold films prepared by vacuum evaporation. By A. E. Ennos, A.Inst.P. (*Associated Electrical Industries Ltd., Aldermaston, Berks*).

Thin gold films formed by vacuum evaporation on to freshly evaporated layers of certain metallic oxides show high conductivity, in a similar way to layers prepared by cathodic sputtering. The evaporated layers are robust and of high current-carrying capacity down to 30 Å thickness. The conductivity approaches the bulk value for annealed films thicker than 60 Å. The properties of these films are discussed in relation to those of the sputtered layers, with which they compare favourably.

The dust-free space surrounding hot bodies. By W. Zernik, Grad.Inst.P. (*Simon-Carves Ltd., Stockport*).

It is generally accepted that the dust-free space around hot bodies is due to the combined action of a radiometer force and an aerodynamic force caused by convection currents but no attempt has yet been made to derive a quantitative theory. Starting from the published work on the derivation of these forces a method has been evolved for equating them and the theory is worked out quantitatively for a vertical plate and for a horizontal cylinder in terms of temperature difference and the properties of the surrounding medium. The resulting relations are in good agreement with published experimental data.

Contact electrification across metal-dielectric and dielectric - dielectric interfaces. By G. S. Rose, A.Inst.P., and S. G. Ward (*University of Birmingham*).

An apparatus is described by means of which a spherical dielectric surface can be compressed under various loads against either a plane metal disk or a plane dielectric disk. A transfer of electric charge across the interface is recorded when the surfaces are separated. The polarity of charging between any two materials depends upon the relative positions of those materials in an electrostatic series ; a metal surface does not always assume a positive charge as found for impact electrification. For two given materials the amount of charge is proportional to the contact area between the surfaces and provided that one of the surfaces has a resistivity above a critical value (5×10^{11} Ω cm) then the charge density for various combinations of materials is approximately proportional to the lower dielectric constant in each combination. This result suggests that the charging may be limited by electrical back-discharge between the separating surfaces. It is considered to be unlikely that the electrification originates from a difference in the contact potentials of the two surfaces involved.

Properties of two-aperture electron lenses. By G. D. Archard, A.Inst.P. (*Associated Electrical Industries Ltd., Aldermaston, Berks*).

Spherical and chromatic aberrations and focal properties of two-aperture (" immersion ") electron lenses are investigated theoretically, and the results are presented graphically as functions of lens geometry and voltage ratio.

Forthcoming Institute Meetings

Mch. 15 Non-Destructive Testing Group — At the Institute's House, 6.30 p.m.
" *The Testing of Coal* " — Tea 5.45 p.m.
Principal Speakers :
Mr. C. D. Pomeroy, A.Inst.P. (Mining Research Establishment, Isleworth)
Mr. W. T. A. Morgans (Mining Research Establishment, Isleworth)
Dr. N. B. Terry, A.Inst.P. (Mining Research Establishment, Isleworth)
Mr. F. J. Hiorns, A.Inst.P. (British Coal Utilization Research Association, Leatherhead)

Mch. 20 London and Home Counties Branch — At the Institute's House, 6.30 p.m.
" *Semi-conductors and the New Electronics* " — Tea 6 p.m.
Dr. R. A. Smith
(Radar Research Establishment, Gt. Malvern)

Apl. 5-6 X-Ray Analysis Group — At University College, Cardiff
Spring Conference
" *Minerals and Inorganic Compounds* "

Details and forms of application can be obtained from the Deputy Secretary of the Institute or from Dr. D. Rogers, F.Inst.P., The Physics Department, University College, Cathays Park, Cardiff.

Apl. 9-11 Stress Analysis Group — At University College, Leicester

Group Annual Conference

Details and forms of application can be obtained from the Deputy Secretary of the Institute.

Apl. 12 Liverpool and North Wales Branch

At the Denbighshire New Technical College, Wrexham, 7 p.m.

"*The Industrial Utilization of Radiation*" — Tea 6.30 p.m.

DR. R. ROBERTS

(Atomic Energy Research Establishment, Harwell)

Apl. 12 Non-Destructive Testing Group — At the Institute's House, 6.30 p.m.

"*Damping Capacity and Fatigue*"

DR. K. M. ENTWHISTLE

Apl. 12-13 Scottish Branch and Education Group

At the Royal College of Science and Technology, Glasgow

A Scottish Conference on Training in Physics

Details and forms of application can be obtained from the Deputy Secretary of the Institute, or from Dr. A. R. Boyle, A.Inst.P., Dobbie McInnes Ltd., 55 Kelvin Avenue, Glasgow, S.W.2.

Physical Society Meetings

Members of the Institute are invited to attend the following meetings of The Physical Society :

Mch. 22 — Low Temperature Group

All-day Discussion Meeting on Low Temperature Distillation

At The Institute of Physics, 11 a.m.—12.30 p.m. and 2.00 p.m.—5.30 p.m.

Apl. 3 — Annual General Meeting — Colour Group

Chairman's Address :

MR. R. G. HORNER

At The Royal Photographic Society, at 3.15 p.m.

Apl. 8-10 — Spring Meeting of the Society

on

"*Physics of the Solid State*"

At the University of Nottingham

Details and forms of application may be obtained from Miss Miles, The Physical Society, 1 Lowther Gardens, Prince Consort Road, London, S.W.7.

Apl. 9 — The Guthrie Lecture

on

"*Some Chemical Limitations on Theories for the Origin of The Solar System*"

PROFESSOR H. C. UREY

At the University of Nottingham

KELVIN & HUGHES LTD.

Physicists, with electronic experience and enthusiasm are required for research and development work on new techniques in echo sounding and non-destructive testing.
Previous experience in ultrasonics would be an asset. For the senior posts, an honours degree is required, for others, a general degree or H.N. Certificate. A commensaurate salary will be paid to men of outstanding ability. Interesting and challenging work in expanding laboratories, permanent and pensionable, good prospects.
Applications, which may be made in the strictest confidence, should give full details of qualifications, previous experience, age and salary required and be addressed to the Personnel Department, New North Road, Barkingside, Essex.

HERTFORDSHIRE COUNTY COUNCIL

NORTH HERTS TECHNICAL COLLEGE

Principal : F. W. Kellaway, B.Sc., Dip.Ed.

Applications are invited for two appointments as Senior Laboratory Stewards to supervise Laboratory Staff
(*a*) in laboratories for pure and applied science.
(*b*) in laboratories for engineering.
Experience in organization of storage and issue of equipment and in construction and repair of apparatus advantageous. Salary £575—£680.
Applications, in full details, should be sent as soon as possible to the Principal, North Herts Technical College, Broadway, Letchworth.

EXTRAMURAL RESEARCH ON COAL AT UNIVERSITIES

Much of the research on new methods of mining, preparing and exploiting coal is carried out for the National Coal Board in the Universities, under the supervision of the Board's Directorate of Extramural Research. There is a vacancy in this Directorate for a good honours physicist, mathematician or research engineer to help with planning and progressing the research, and assimilating its results. Duties will include visits to University Research Departments, and some experience of University research would be an advantage. A wide range of problems and interests, both fundamental and applied, is covered. Appointment (superannuable) within inclusive scales as either Scientist Grade 2 (£991 to £1,390 male) or Scientist 3 (£617 to £1,124 male) according to qualifications and experience.
Write, with full particulars of age, education, qualifications and experience, to National Coal Board, Staff Department, Hobart House, London, S.W.1, marking envelope X/594/D, before March 19, 1957.

PHYSICISTS. Applications are invited for the following positions in the Department of Physics, University of Manitoba, Winnipeg, Canada. Professorship, salary $7,400 and up and Associate Professorship, $6,300 to $7,300. Also two one year appointments as Assistant Professor, salary $5,000 to $6,200, or Lecturer, salary up to $4,900. Apply to Dean of Arts and Science giving information as to qualifications, experience and references. Commencing date September 1, 1957.

A NEW PROJECT
ON
TRANSISTORS AND SEMI-CONDUCTOR DEVICES

offers many new openings to first-class men qualified in Electronic, Electrical and Mechanical Engineering, Physics, Chemistry and Mathematics.
Group Leaders, Senior and Junior graduate Engineers are required for :—

1. Device development.
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OTHER VACANCIES

6. Valve applications engineer (Senior) for varied circuitry work.
7. Assistant Chief Chemist (28-35) with good honours degree and experience in electro-chemical industry essential.
8. Valve development engineer (senior)
9. C.R.T. development engineer (senior)
10. Circuit engineers (senior and intermediate) for electronic control equipment, industrial monitors and radio/T.V. receivers.

Attractive salaries are being offered, non-contributory pension scheme, and good terms and conditions of service.
Anyone interested is invited to write with details in confidence to :—

Mr. W. J. Yeomans, Personnel Manager

STANDARD TELEPHONES AND CABLES LTD.,
FOOTSCRAY, SIDCUP, KENT.

B T-H

British Thomson-Houston Co. Ltd. have vacancies in their Research Laboratories at Rugby for graduate physicists (male or female) to carry out investigations, both fundamental and short term, in a number of different research projects. Previous research experience is not essential for some of the posts, but it is envisaged that applicants with such experience or higher degrees would subsequently lead small research teams.

These posts offer excellent opportunities for carrying out original research unhampered by equipment difficulties. Every facility is given for the publication of results and for participating in other scientific activities.

Applicants are invited to write to the Director of Research, British Thomson-Houston Co. Ltd., Rugby, giving particulars of age, qualifications and experience, quoting reference WB.

IMPERIAL CHEMICAL INDUSTRIES LIMITED

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UNIVERSITY GRADUATE PHYSICISTS

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TRAINING FOR MANAGEMENT

Training, not necessarily confined to the instrument field, will be adjusted to previous experience. A good degree is essential. Initial duties will include investigations into the application of automatic control, instrumentation, and method study in the organic chemical and synthetic fibres fields. After joining the staff, married men will receive a reasonable refund of removal expenses and facilities are available for assistance with house purchase. Applications, with brief details of age, qualifications and experience, to Staff Department, Hexagon House, Blackley, Manchester, 9, quoting reference 1/74.

UNIVERSITY OF GLASGOW

UNIVERSITY STUDENTSHIPS AND FELLOWSHIPS

Applications are invited for University Studentships and Fellowships for experimental or theoretical research in nuclear and elementary particle physics. Salary scale :—

Studentships : £350—£500 per annum, according to qualifications, with a tenure of three years.

Fellowships : £600—£800 per annum, according to qualifications. Tenure three years on appointment, with possible renewal for further period of two years. These Fellowships will be superannuated under the F.S.S.U.

Applications stating age, academic qualifications, research experience and names of two referees, should be sent to the Professor of Natural Philosophy, The University, Glasgow, W.2, before March 30, 1957.

WOOL INDUSTRIES RESEARCH ASSOCIATION

Physicist with 1st or 2nd class honours degree or A.Inst.P., preferably with research experience, required for fundamental research on the infra-red spectroscopy of proteins and related substances. Publication of results encouraged, and facilities available to work for Ph.D.

Commencing salary according to age and experience in the range £585—£1,025 p.a. with F.S.S.U. benefits. Applications to the Association, Torridon, Headingley, Leeds, 6.

PLESSEY NUCLEONICS LTD., have a vacancy for a Physicist whose interest lies in devising and carrying out basic experiments. The successful applicant will become a member of a team engaged upon designing new methods and instruments for nuclear reactor measurement and control. Considerable scope will be given to develop new and original ideas. The salary for this post will be on a generous scale depending upon previous experience and qualifications. Applicants should write in confidence giving full particulars to the Chief Engineer, Plessey Nucleonics Ltd., Weedon Road, Northampton.

HERTFORDSHIRE COUNTY COUNCIL
NORTH HERTS TECHNICAL COLLEGE
Principal : F. W. Kellaway, B.Sc., Dip.Ed.

Applications are invited for the new appointment as Senior Lecturer in Physics to teach to Higher National Certificate in Applied Physics and beyond. Higher degree and research and/or industrial experience desirable in addition to teaching experience. Facilities for development of courses, and research will be available in new laboratories.
Salary £1,350 to £1,550.
Full details may be obtained by sending a stamped addressed envelope to the Principal, North Herts Technical College, Broadway, Letchworth.

ROYAL TECHNICAL COLLEGE, SALFORD
Acting Principal : J. F. Yates, B.Sc., M.Sc., M.I.E.E.
This College is now recognized by the Ministry of Education as one of Advanced Technology, and the Governors invite applications for the posts of Senior Lecturer and Lecturer in the Physics Department. Candidates should have had some teaching and research experience.
The salary will be in accordance with the Burnham Technical Scale, viz. Senior Lecturer £1,350—£1,550 (men) ; £1,080—£1,240 + 3/7ths differential from April (women). Lecturer £1,200—£1,350 (men) ; £960—£1,080 + 3/7ths differential from April (women).
The successful candidates will be required to commence duty as soon as possible after May 1, 1957.
For further particulars and forms of application please send a stamped addressed envelope to the Acting Principal, Royal Technical College, Salford, 5, to whom applications should be returned as soon as possible.

R. Ribblesdale Thornton,
Clerk to the Governors.

NON-DESTRUCTIVE TESTING TECHNIQUES
Attractive and responsible positions are offered in the development of new techniques for the non-destructive examination of materials.
Senior and junior staff are required with qualifications or experience in the fields of physics or physical metallurgy with particular reference to the non-destructive examination of materials or industrial instrumentation and measurement. Salaries commensurate with qualifications and experience will be paid.

Application should be made in writing in the first instance giving full details of qualifications, previous experience, age and salary required, and be addressed to : Personnel Department, Kelvin & Hughes Ltd., New North Road, Barkingside, Essex.

BRITISH

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PHYSICISTS

in its

Research and Development

Laboratories

as follows :

Physicist, age 25/50, to lead a team of chemists, physicists and engineers engaged upon the laboratory and plant development of plastic films other than cellulose and polythene. Candidates should have an honours degree—a higher degree would be an advantage. Practical experience of research and development work on a laboratory and pilot plant scale, and the co-ordination of the work of graduate staff, essential. Ref. No. R50. IP.

Physicists, age 25/50, of honours degree standard. The work involved will be laboratory, pilot plant, and plant scale development in connexion with cellulose and plastic films. Previous related experience is desirable but not essential.
Ref. No. R51. IP.

Application forms may be obtained from the Personnel Officer, British Cellophane Limited, Bridgwater, Somerset.

IMPERIAL CHEMICAL INDUSTRIES LIMITED

Dyestuffs Division
have a vacancy in their
RESEARCH LABORATORIES
for a
PHYSICIST

to undertake the development of new methods of mass-spectrometry. The work will involve the design and construction of special apparatus and, later, its application to investigations of a non-routine nature. Applicants should hold a good Honours degree in physics, possess some experience of electronics and preferably have an interest in chemical physics. Salary will be in accordance with qualifications and experience. Profit sharing and pension schemes are in operation, and, in appropriate cases, assistance can be given with housing. Write to the Staff Manager, Imperial Chemical Industries Limited, Dyestuffs Division, Hexagon House, Blackley, Manchester, 9, giving very brief details of age, experience and qualifications. Please quote Ref. I.63/Phys.

UNIVERSITY OF ST. ANDREWS
LECTURESHIP IN PHYSICS

The University Court of the University of St. Andrews invites applications for a Lectureship in Physics in Queen's College, Dundee. The appointment will date from October 1, 1957. The salary will be on the scale £650 × £50 – £1,350 per annum (subject to an efficiency bar at £1,000), commencing salary according to qualifications and experience. The post carries F.S.S.U. benefits and family allowances, and a grant towards expenses of removal will be made. Further particulars may be obtained from the undersigned, with whom five copies of the application, together with the names of three referees, should be lodged not later than April 30, 1957.

Patrick Cumming,
Joint Clerk to the University Court.
Queen's College, Dundee.

Chartered Patent Agents

W. H. BECK, GREENER & CO.

7 Stone Buildings,
Lincoln's Inn,
Chancery 2535 London, W.C.2

THE CLAYTON DYESTUFFS CO. LTD., Manchester, 11, have vacancies in their Technical Service Laboratories for Graduate Physicists and Chemists for development work on the application of chemical finishes to textiles and other substrates. There are very good opportunities for advancement and there is an excellent pension scheme. Applications should be made to the Secretary.

EDITOR for Section A (Physics) of *Science Abstracts*. Science degree, or corresponding qualification, needed, and some knowledge of most branches of physics. Acquaintance with foreign languages essential and experience of a research or design department, or of information work connected with such, is desirable. Commencing salary commensurate with age and experience. Pension scheme. Apply to Secretary, Institution of Electrical Engineers, Savoy Place, W.C.2.

PHYSICIST required to set up and lead research department for investigating problems concerned with heat transfer and light electrical control systems. This department is a new venture by a large and expanding group of companies with excellent prospects for an ambitious man with practical engineering and research experience. Please state age, experience and salary required to The Secretary, Biddle Holdings Ltd., 16 Upper Grosvenor Street, W.1.

AUSTRALIAN DEFENCE SCIENTIFIC SERVICE

PHYSICAL METALLURGY

The Defence Standards Laboratories of the Department of Supply, Melbourne, invite applications for a position of

SCIENTIFIC OFFICER, GRADE 1

from Honours Graduates in Science or Engineering with Metallurgy as a major subject. Applications from candidates about to take an Honours Degree will also be considered.

SALARY : **£1,287/1,602**

DUTIES : Research in the field of Physical Metallurgy ; at present, study of embrittlement of titanium alloys at moderately elevated temperatures.

The Salary quoted is Australian currency.

Whilst the position is classified as temporary, the tenure of employment is not limited, and after a specified period the appointee will be able to apply for entry to the Commonwealth Superannuation Scheme. First class boat fare for the appointee and dependants (wife and dependant children) will be paid under specified conditions by the Commonwealth of Australia.

Application forms and further particulars obtainable from

Senior Representative (AP.76),
Department of Supply,
Australia House,
Strand,
LONDON, W.C.2,

with whom applications should be lodged by 28/3/57.

Appointments Vacant

The inclusion of particulars of a vacancy must not be taken to imply that the Institute necessarily approves of the terms offered or that might be offered. Candidates should satisfy themselves that these are satisfactory, and they may always refer to the Institute for advice.

SCIENCE MUSEUM : ASSISTANT KEEPER. The Civil Service Commissioners invite applications for a pensionable post in the Department of Physics. Appointment will be to Assistant Keeper first or second class according to age and qualifications.

Age at least 22 and under 26 on March 1, 1957, for second class appointment, with extension for Forces service, established civil service, and exceptionally well qualified candidates. For first class appointment candidates must normally be at least 30 on March 1, 1957, but candidates aged 28–30 would be considered exceptionally.

Candidates must have 1st or 2nd class honours degree in physics or an equivalent qualification. Post-graduate experience and knowledge of one or more foreign languages are advantages.

Salary scales (men)—£1,120–£1,760 or £605–£855 according to grade. Women's scales somewhat lower but being improved to reach equality with men's by 1961. For a class II appointment starting pay may be increased for approved postgraduate experience and for compulsory Forces service. Prospects of promotion.

Further particulars and application forms from Secretary, Civil Service Commission, Scientific Branch, 30 Old Burlington Street, London, W.1, quoting S4677/57/9. Completed application forms should be returned by April 17, 1957.

RESEARCH LABORATORY
ASSOCIATED ELECTRICAL INDUSTRIES LTD.
ALDERMASTON COURT

Research Application of Radioactivity. Graduate Scientist required by a long-term Research Laboratory to specialize in this subject. Qualifications required are a degree, or equivalent, in physics, chemistry or metallurgy ; some research experience is desirable and a knowledge of radioactive tracer techniques and apparatus would be an advantage. The starting salary will depend upon the qualifications and experience, but will be within the range £600–£1,000. The Laboratory serves a large group of companies. It is situated in pleasant rural surroundings near Reading with a fast train service to London. Please write giving full details of qualifications and experience quoting references No. S/G/7 to Personnel Officer, Research Laboratory, Associated Electrical Industries Ltd., Aldermaston Court, Aldermaston, Berkshire.

INDUSTRIAL ELECTRONICS

A senior Engineer is required to undertake work on a variety of projects in the Industrial Electronic field. The applicant should have an honours degree in physics or electrical engineering, and be capable of leading a team. The salary will be in accordance with age, qualifications and experience. All applications will be treated as confidential and should be addressed to The Employment Manager, The Plessey Co. Ltd., Vicarage Lane, Ilford, Essex.

NORTH STAFFORDSHIRE TECHNICAL COLLEGE
STOKE-ON-TRENT

Principal : H. W. Webb, O.B.E., D.Sc.

Applications are invited for the post of full-time Lecturer in Physics to commence duties on September 1 next. Candidates should have a good physics degree or be corporate members of The Institute of Physics, and should preferably have had teaching experience. Special experience and interest in the field of industrial instrumentation or instrument design would be an advantage, but candidates offering qualifications or experience in other branches of applied physics such as spectroscopy, X-ray diffraction or applications of nuclear physics, etc., will be favourably considered. Burnham Technical Scale of salaries : £1,200 × £30–£1,350 per annum. Applications giving details of age, qualifications, training and experience together with the names of two referees, should be sent to the Principal on or before April 20, 1957.

H. Dibden,
Clerk to the Governors

DEPARTMENT OF PHYSICS

UNIVERSITY COLLEGE
CARDIFF

A RESEARCH ASSISTANT is required for work on identification by X-ray diffraction methods. Qualifications : some knowledge of electronics ; interest in X-ray methods ; degree or Grad.Inst.P. desirable. The post, which is renewable from year to year, may offer scope for research for the degree of M.Sc. Duties to commence on October 1, 1957, or earlier if convenient.

Salary until July 31, 1957 : in the range £500 × £50 to £650. Salary after August 1, 1957 : in the range £700 × £50 to £850. F.S.S.U. for candidates satisfying the requirements.

Further information may be obtained from

Professor A. J. C. Wilson,
University College, Cardiff, Great Britain.

Three copies of applications are required.

A NEW PROJECT
ON
TRANSISTORS AND SEMI-CONDUCTOR DEVICES

offers many new openings to first-class men qualified in Electronic, Electrical and Mechanical Engineering, Physics, Chemistry and Mathematics.

Group Leaders, Senior and Junior graduate Engineers are required for :—

1. Device development.
2. Mechanical development.
3. Control instrumentation.
4. Electrical measurements and Applications.
5. Design and Specifications Group. Original thinkers are in particular demand for this important Group.

OTHER VACANCIES

6. Valve applications engineer (Senior) for varied circuitry work.
7. Assistant Chief Chemist (28-35) with good honours degree and experience in electro-chemical industry essential.
8. Valve development engineer (senior)
9. C.R.T. development engineer (senior)
10. Circuit engineers (senior and intermediate) for electronic control equipment, industrial monitors and radio/T.V. receivers.

Attractive salaries are being offered, non-contributory pension scheme, and good terms and conditions of service.

Anyone interested is invited to write with details in confidence to :—

Mr. W. J. Yeomans, Personnel Manager

STANDARD TELEPHONES AND CABLES LTD.,
FOOTSCRAY, SIDCUP, KENT.

NON-DESTRUCTIVE TESTING TECHNIQUES

Two attractive positions are offered which will involve hard work and extensive travelling in the United Kingdom and Europe. The successful applicants will be concerned with the development and industrial application of modern non-destructive testing techniques. They must have the following qualifications:

1. Initiative
2. Experience in the industrial application of modern electronic techniques and/or mechanical design. It is desirable that they should also have adequate academic qualifications.
3. Age 23 to 30 years.
4. Salaries will commensurate with the candidate's qualifications and experience.

Application should be made in writing in the first instance giving full details of qualifications, previous experience, age and salary required, and be addressed to : Personnel Department, Kelvin & Hughes Ltd., New North Road, Barkingside, Essex.

BRITISH CELLOPHANE LTD. have vacancies for honours degree physicists interested in production technology, and with the ability to assume responsible posts later. Applicants are invited to submit in confidence full details of their qualifications and experience. Initial work will comprise plant-scale investigations into production problems. Adequate salaries to the right men. Please quote ref. no. M21.IP.

Application forms may be obtained from the Personnel Officer, British Cellophane Ltd., Bath Road, Bridgwater, Somerset.

NORTHERN POLYTECHNIC,
HOLLOWAY, LONDON, N.7

The Governing Body invites immediate applications for appointment as Lecturer in the Department of Physics, to teach up to the standard of the B.Sc. Special Degree and its technological equivalent. Facilities are available for participation in research. Salary scale: Men—£1,200 × £30–£1,350; Women—£1,062 by equal pay increments to £1,350 ; plus London allowance.

A suitably qualified candidate will be considered for appointment as Senior Lecturer. Salary scale : Men—£1,350 × £50–£1,550; Women—£1,195 by equal pay increments to £1,550 ; plus London allowance.

Particulars and form of application may be obtained from the Clerk to the Governors.

THE BRITISH IRON AND STEEL RESEARCH ASSOCIATION
REQUIRES A
GRADUATE PHYSICIST

for design and development work in the field of instrumentation for industry and research. Capacity for original thinking is as important as specialist experience. Good knowledge of applied physics essential, allied to an aptitude for experimental work. Location of work London, S.W.11. Starting salary up to £900 p.a. according to age, qualifications and experience. Post is superannuated under the F.S.S.U. Written applications only, quoting P.Y.1. to the Personnel Officer, B.I.S.R.A., 11 Park Lane, London, W.1.

CENTRAL ELECTRICITY AUTHORITY require Physicists to undertake work on the non-destructive testing of materials for conventional and nuclear power stations at the Research Laboratories, Leatherhead, Surrey. Candidates should have an honours degree or equivalent. Specialized experience in one branch of non-destructive testing an asset, although a broad knowledge or experience in the whole field preferred. Work consists more in developing and applying techniques rather than in actual routine testing. Salaries within scales £930–£1,345 per annum according to ability.
Application forms, obtainable from D. Moffat, Director of Establishments, Winsley Street, London, W.1, should be completed and returned by April 23, quoting ref. BIP/121.

UNIVERSITY OF GLASGOW
UNIVERSITY STUDENTSHIPS AND FELLOWSHIPS

Applications are invited for University Studentships and Fellowships for experimental or theoretical research in solid state physics. Salary scale :—
Studentships : £350—£500 per annum, according to qualifications, with a tenure of three years.
Fellowships : £600—£900 per annum, according to qualifications. Tenure three years on appointment, with possible renewal for further period of two years. These Fellowships will be superannuated under the F.S.S.U.
Applications stating age, academic qualifications, research experience and names of two referees, should be sent to the Professor of Natural Philosophy, The University, Glasgow, W.2, before April 30, 1957.

FULMER RESEARCH INSTITUTE LTD.

The Fulmer Research Institute requires the services of two graduate physical chemists, or of graduates in metallurgy or physics who have an interest in physical chemistry. The work will be chiefly concerned with thermodynamic and thermochemical determinations in the field of inorganic compounds and alloy systems. It is likely that the results of the work will be published. Salary according to qualifications and experience in the range of £650–£850 p.a. for a young graduate.
Apply : The Director, Fulmer Research Institute, Stoke Poges, Bucks.

PLESSEY NUCLEONICS LTD., have a vacancy for a Physicist to carry out original work on radiation detection devices. Applicants should possess a degree in physics and could have an interest in mathematical physics. Alternatively, an interest in the application of electronics to reactor instrumentation and control or in the field of reactor physics would be desirable. A generous salary will be offered, based upon qualifications and previous experience. Please write in confidence giving full particulars to The Chief Engineer, Plessey Nucleonics Ltd., Weedon Road, Northampton.

FERRITE/TRANSISTORS. A senior engineer with experience of ferrites and a knowledge of computer technique is required by The Plessey Co. Ltd., Vicarage Lane, Ilford, Essex. Salary will be in accordance with age, qualifications and experience. All applications will be treated as confidential and should be sent to the Employment Manager.

METALLURGIST or PHYSICIST aged 25 to 30 required to take charge of Non-Destructive Testing of materials in Engineering Works engaged on the production of Nuclear Power Plant. Applicants should have had experience in the X-ray and Gamma Ray examination of castings, welds, etc., preferably some experience in the Ultrasonic flow detection of forgings and should be capable of developing new techniques where required. Apply giving full details of experience and qualifications to Personnel Manager (M.L.), The General Electric Co. Ltd., Fraser & Chalmers Engineering Works, Erith, Kent.

PHYSICIST with B.Sc. degree or equivalent, interested in light and optics, required for work on colours of printing inks and photomicrography of printing materials. The successful candidates will be required to possess normal or near normal colour vision. F.S.S.U. Salary on scale £650–£1,100 according to age, qualifications and experience. Application forms from Secretary, Printing, Packaging and Allied Trades Research Association, Patra House, Randalls Road, Leatherhead (Ref. P/O.3/57).

PHYSICIST or ELECTRICAL/MECHANICAL ENGINEER required by Ministry of Supply at R.A.E., Farnborough, Hants, to carry out research on electro-mechanical instruments used for flight testing aircraft and missiles. Candidates should have 1st or 2nd class honours degree or equivalent in physics or electrical or mechanical engineering. Experience appropriate to duties desirable. Appointment as Scientific Officer (min. age 21) with salary in range £565–£995 (superannuable). Forms from M.L.N.S., Technical and Scientific Register (K), 26 King Street, London, S.W.1, quoting A91/7A. Closing date May 24, 1957.

MINISTRY OF SUPPLY invites applications for a limited number of Senior and Junior Research Fellowships tenable for three years at the Radar Research Establishment, commencing Autumn, 1957. Fellows will be allowed considerable choice of subjects within the fields of interest to the Establishment. These include experimental and theoretical research in low temperature physics, electrical and optical properties of semi-conductors, infra-red spectroscopy, microwave physics, and electronics.
Candidates should normally have a first or second class honours degree in an appropriate subject, and must be able to show evidence of a very high standard of ability in research. Exceptionally a candidate without the requisite academic qualification, but who can produce evidence of outstanding ability in research, may be admitted. At least two years' post-graduate research experience will be expected of candidates for Junior Fellowships who should preferably be aged 23–26 and at least three years for Senior Fellowships who should preferably be aged 26–30.
Remuneration will depend on individual merit and will be between £1,000 and £1,200 per year for Senior Fellows and £650—£850 per year for Junior Fellows. Superannuation under F.S.S.U. At the expiry of a Fellowship the holder, if of a suitable age, may be considered for an established post if he so desires.
Application forms are obtainable from the Director, Radar Research Establishment, Malvern, Worcs, to whom they must be returned by April 24, 1957.

METROPOLITAN-VICKERS
ELECTRICAL CO LTD. · TRAFFORD PARK · MANCHESTER 17

ENGINEERS AND PHYSICISTS

There are opportunities for Engineers and Physicists in the Research Department and Scientific Apparatus Department of the Company.

An important field of interest is that in which electrons or ions are produced and utilized in vacuum. Specific applications are found in particle accelerators, high power radio valves, electron microscopes, mass spectrometers, etc. Work, of a fundamental and developmental nature, is in progress, and there are openings for men with either academic or practical interests.

Conditions of employment compare favourably with other industrial organizations.

Opportunity is given for original work and the publication of papers is encouraged.

Application should, in the first instance, be made to

THE MANAGER, RESEARCH DEPARTMENT,
METROPOLITAN-VICKERS ELECTRICAL CO. LTD., TRAFFORD PARK, MANCHESTER, 17.

Quoting reference " C.P.8 "

PHYSICIST or AERONAUTICAL ENGINEER required by Ministry of Supply London H.Q., to be responsible under head of section for initiating and progressing research and 'development of airborne oxygen equipment in industry and at R.A.E., Farnborough for operational requirements ; for technically approving equipment and introducing it to Services ; for arranging and assessing service trials. 1st or 2nd class honours degree or equivalent in physics or aeronautical engineering necessary. Experience in oxygen field not essential, but knowledge of instrumentation practice desirable. Minimum three years' postgraduate research experience including some in research and development of aircraft or aircraft equipment, and ability to negotiate with industry required. Senior Scientific Officer (min. age 26) salary range £1,135–£1,345 (superannuable). Forms from M.L.N.S., Technical and Scientific Register (K), 26 King Street, London, S.W.1, quoting A98/7A. Closing date May 24, 1957.

PHYSICIST or AERODYNAMICIST required by Ministry of Supply at R.A.E., Bedford, to work in section responsible for study and assessment of different approach and landing systems on existing and advanced civil and service aircraft ; research on problems associated with transition from instruments to visual aids. Candidates should have 1st or 2nd class honours degree or equivalent, in physics or aerodynamics. Experience of aircraft landing forms, servo-mechanisms and simulators an advantage. Appointment as Scientific Officer (min. age 21) Salary within range £565–£995 p.a. (superannuable). Forms from M.L.N.S., Technical and Scientific Register (K), 26 King Street, London, S.W.1, quoting A75/7A. Closing date, April 24, 1957.

UNIVERSITY COLLEGE OF RHODESIA AND NYASALAND

Applications are invited for a Lectureship in Physics. Salary scales : Assistant Lecturer £1,050 × £50–£1,200 p.a. Lecturer (Grade II) £1,200 × £50–£1,450 p.a., (Grade I) £1,450 × £50–£1,750 p.a., point of entry determined by qualifications and experience. Superannuation Scheme. Passages to Salisbury for appointee, wife and dependent children on appointment with allowance for transport of effects. Unfurnished accommodation at rent up to 15 per cent of salary.

Detailed applications (six copies) naming three referees by May 4, 1957, to Secretary, Inter-University Council for Higher Education Overseas, 29 Woburn Square, London, W.C.1, from whom further particulars may be obtained.

PHYSICIST or ENGINEER required by Ministry of Supply at R.A.E., Bedford, to be member of control team working on problems associated with all-weather approach and landing of aircraft, including fully automatic landing. Candidates should have 1st or 2nd class honours degree or equivalent in physics or engineering. Some knowledge of servo-mechanisms and/or use of analogue computors an advantage. Candidates should be prepared to do limited amount of flying. Appointment as Scientific Officer (min. age 21). Salary within range £565–£995 p.a. (superannuable). Forms from M.L.N.S., Technical and Scientific Register (K), 26 King Street, London, S.W.1, quoting A76/7A. Closing date, April 24, 1957.